PB85-107175

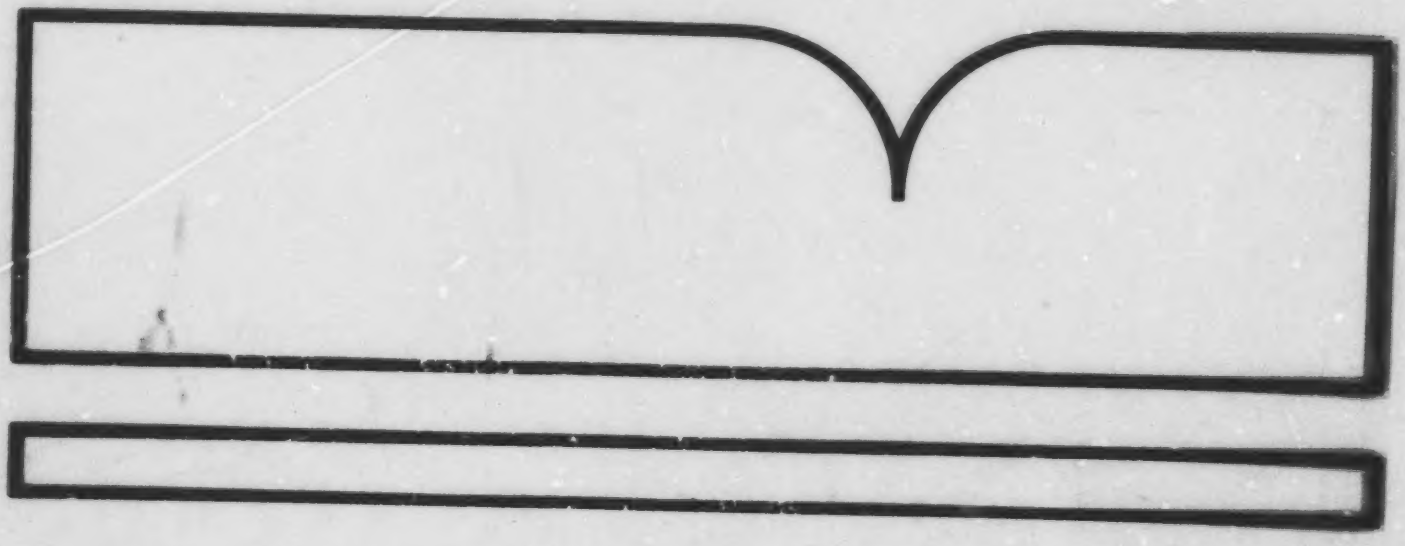
Heavy-Duty Engine Exhaust Particulate Trap Evaluation

Southwest Research Inst., San Antonio, TX

Prepared for

Environmental Protection Agency, Ann Arbor, MI

Sep 84



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TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA 460/3-84-008	2.
3. RECIPIENT'S ACCESSION NO. PB85 107175	
4. TITLE AND SUBTITLE Heavy-Duty Engine Exhaust Particulate Trap Evaluation	5. REPORT DATE September 1984
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Charles M. Urban	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Southwest Research Institute 6220 Culebra Road San Antonio, Texas 78284	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO. 68-03-3162 Work Assign, No. 3
12. SPONSORING AGENCY NAME AND ADDRESS Environmental Protection Agency 2565 Plymouth Raod Ann Arbor, Michigan 48105	13. TYPE OF REPORT AND PERIOD COVERED Final (7/25/83 - 7/25/84)
	14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES	

16. ABSTRACT

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17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Exhaust Emissions Diesel Engines	Heavy-Duty Engines Particulate Emissions Control	

18. DISTRIBUTION STATEMENT Release Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 88
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

PB85-107175

United States
Environmental Protection
Agency

Office of Mobile Source Air Pollution Control
Emission Control Technology Division
2565 Plymouth Road
Ann Arbor, Michigan 48105

EPA 460/3-84-008
September 1984

Air

EPA

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NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

EPA 460/3-84-008

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ENVIRONMENTAL PROTECTION AGENCY
Office of Mobile Source Air Pollution Control
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2565 Plymouth Road
Ann Arbor, Michigan 48105

September 1984

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Publication No. EPA 460/3-84-008

FOREWORD

This Work Assignment was initiated by the Technology Assessment and Evaluation Branch, Environmental Protection Agency, 2565 Plymouth Road, Ann Arbor, Michigan 48105. The engineering and analytical effort on which this report is based was accomplished by the Department of Emissions Research of Southwest Research Institute, 6220 Culebra Road, San Antonio, Texas 78284. This project, authorized by Work Assignment No. 3 of Contract 68-03-3162, was initiated on July 25, 1983 and was completed July 25, 1984.

The SwRI Project Leader was Mr. Charles M. Urban, who supervised all evaluations, data analyses, and reporting. Mr. Charles T. Hare was Project Manager, and was involved in the initial technical and fiscal negotiations and subsequent major project decisions.

The Project Officer was Mr. Robert J. Garbe of the Technical Support Staff, Environmental Protection Agency. The Branch Technical Representative was Mr. Robert Wagner of the Control Technology Assessment and Characterization Branch, Environmental Protection Agency.

ABSTRACT

This report describes a laboratory effo . to evaluate several aspects of the use of exhaust particulate traps with heavy-duty diesel engines. The effort involved: monitoring exhaust temperatures in heavy-duty vehicles operating on a chassis dynamometer; design and evaluation of a particulate trap bypass system; regeneration of particulate traps; and exhaust emissions evaluations of a heavy-duty diesel engine, with and without exhaust particulate traps.

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SUMMARY

This project work assignment involved a laboratory effort to evaluate several aspects of the use of exhaust particulate traps with heavy-duty diesel engines. The effort involved: monitoring exhaust temperatures in heavy-duty vehicles operating on a chassis dynamometer; design and evaluation of a particulate trap bypass system; and exhaust emissions evaluations of a heavy-duty diesel engine, with and without exhaust particulate traps.

During transient operation of heavy-duty vehicles on the chassis dynamometer and with a Cummins NTC-400 engine on an engine dynamometer, exhaust gas temperatures downstream of the turbocharger failed to reach the level required for regeneration of particulate traps. In steady-state operation, temperatures necessary for regeneration in a location downstream of the turbocharger occurred only during operation at lower engine speeds with high power output. In a pre-turbocharger location on the NTC-400 engine, the nominal 600°C temperature necessary for regeneration of particulate traps was attained for a very short period of time during operation over the transient cycle.

A particulate trap bypass system was designed and assembled, and it basically functioned as intended while in operation of an engine on an engine dynamometer test stand. Application of such a system to an actual vehicle was outside the scope of this work assignment.

During engine operation over the transient cycle, some regeneration was obtained with a single particulate trap close-coupled between the engine exhaust manifold and the turbocharger. With pre-turbocharger-mounted particulate traps, system mass appears to be a major factor affecting engine performance during cold-start and transient operation. It appears that system optimization could significantly improve cold-start and transient operation of the engine, as well as reliability of regeneration of the trap.

Based on results obtained during heavy-duty engine transient cycle operation, some method of increasing exhaust temperature and/or duration at elevated temperature will be required to assure effective regeneration of uncatalyzed particulate traps in heavy-duty applications. The potential applicability of a particulate trap bypass system appears to be dependent on the methods used in attaining the conditions necessary for regeneration.

I. INTRODUCTION

This report describes a laboratory effort to evaluate several aspects of the use of exhaust particulate traps with heavy-duty diesel engines. Primary portions of this effort involved a particulate trap bypass system and unassisted regeneration of particulate traps.

A. Objective

The major objective of the work assignment was to evaluate a regeneration/bypass concept for use in application of exhaust particulate traps to heavy-duty diesel applications.

B. Approach

The approach taken involved four tasks:

Task 1 - Heavy-Duty Exhaust Monitoring - This task involved measurement of exhaust temperature and oxygen content of heavy-duty diesel vehicles tested on a chassis dynamometer under separate EPA Contract 68-02-3722.

Task 2 - Baseline Testing of a Heavy-Duty Diesel Engine - This task involved obtaining exhaust emissions and temperature data on a Cummins NTC-400 diesel engine. The testing included both steady-state and transient operation of the engine.

Task 3 - Bypass Regeneration System Design - This task involved the design of a laboratory prototype particulate trap bypass system for use in demonstrating "proof of concept." The purpose of the bypass system is to provide bypass flow around a loaded particulate trap until conditions for regeneration are attained in the exhaust.

Task 4 - Evaluation of the Regeneration/Bypass System on the Engine - The desired goal was consistent regeneration of the particulate trap during operation over the transient engine test cycle (i.e., regeneration under "normal operation" of the engine). The bypass system was intended to protect against overloading the trap with particulate should the engine be operated under conditions at which regeneration does not occur. A particulate trap with excessive collected particulate is subject to destructive regeneration when uncontrolled ignition of the particulate does occur.

II. GENERAL EQUIPMENT, PREPARATIONS AND PROCEDURES

This section briefly describes the engine, fuel, facilities, and procedures used in this project work assigment. Since the emissions procedures used are documented in the Code of Federal Regulations, they will only be referenced in this section.

A. Engine

A Cummins NTC-400 engine, Serial Number 11080759, was furnished by Cummins Engine Company, Inc. on Test Engine Agreement No. 445 for use in this work assignment. This engine was rated at 400 horsepower at an engine speed of 2100 rpm, and had a rated peak torque speed of 1300 rpm. Idle speed of the engine was 600 rpm. The model-serial number of the injection pump was 3017808-13917-00. Specified exhaust restriction, at engine operating conditions of 2100 rpm full load, was two inches of mercury for transient evaluations; and the intake restriction was 20 inches of water.

B. Particulate Traps

The major portion of the evaluations involving particulate filtration were conducted using Corning Type EX47 cellular ceramic diesel particulate traps procured from Corning Glass Works. The substrates from Corning were selected solely on the basis of their apparent suitability in meeting the requirements and needs of this project task. These substrates consisted of nine separate pieces cemented together, and were 11.25 inches diameter by 12 inches long. The substrates were mounted into stainless steel enclosures by Arvin Automotive, using Diesel Particulate Trap Ass'y Part No. 945280. Two of these units in parallel were recommended for use with the NTC-400 engine.

Near the end of the laboratory evaluations, "catalyzed" metal mesh particulate trap Number CTO-JM13/VI, originally designed for a fourteen liter turbocharged engine, was provided by Johnson Matthey. It was specified that this unit be mounted within three feet of the outlet of the turbocharger, and that it did not require insulation. The design direction of exhaust gas flow through this cylindrical trap was from the outside in, and the particulate loading was to be limited to the amount producing a doubling of the pressure drop across the trap.

C. Fuel

The two test fuels used in this work assignment were D-2 emissions control fuels from Phillips Chemical Company, coded by SwRI as EM-528 and EM-597. Properties of these fuels are given in Table 1. The EM-597 test fuel was used for all evaluations subsequent to the initial baseline and engine mapping evaluations. Sulfur content of the fuels used in all evaluations involving exhaust particulate traps was 0.35 weight percent.

TABLE 1. PROPERTIES OF PHILLIPS D-2 DIESEL CONTROL FUEL

	EM-528 Lot C-747[a]	EM-59? Lot G-075	EPA Spec.[b]	Test Method
Cetane Number	47.5	46.2	42-50	D613
Distillation Range				
IBP, °F	386	375	340-400	D86
10% Point, °F	430	431	400-460	
50% Point, °F	506	487	470-540	
90% Point, °F	576	598	550-610	
End Point, °F	610	653	580-660	
Gravity, °API	35.8	35.2	33-37	D287
Total Sulfur, wt. %	0.22	0.35	0.2-0.5	D3120
Aromatics (FIA), vol. %	29.1	32.1	27 min.	D1319
Kinematic Viscosity (cS)	2.5	2.5	2.0-3.2	D445
Flash Point (PM), °F	157	162	130° min.	D93
Cloud Point, °F	-2	+12	--	D2500
Elemental Anal., wt. %				
C	86.85	86.12	--	Chrom.
H	13.00	12.92	--	Chrom.
C/H	6.68	6.66		Calc.

[a]10.0 ptb of DuPont FOA #11 antioxidant enhances the stability of this fuel.
[b]Diesel fuel as described in Chapter One - Environmental Protection Agency, Subsection 86.113-78, of the Code of Federal Regulations.

D. Dynamometer Test Cell

Test Cell Number 5, a test cell capable of operation over the heavy-duty engine transient cycle, was used for the evaluations conducted under this work assignment. In the initial engine baseline and mapping evaluations, the dynamometer control circuitry was found incapable of handling the power output of this engine during transient operation. Prior to the evaluation of the exhaust particulate traps, the control circuitry was modified to enable operation of the 400 horsepower engine used.

The constant volume sampler (CVS) used for these evaluations was CVS Number 10. The total CVS flowrate used was 54.3 m^3/min (1900 cfm). A double dilution tunnel with a secondary flowrate of 10.6 m^3/min (375 cfm) and a dilution ratio of three was used to prepare the exhaust sample for particulate measurement.

E. Instrumentation and Procedure

Gaseous emissions instrumentation and procedures were in accord with the regulations for 1984 model year heavy-duty engines.(1) Particulate emissions measurement was in accord with proposed particulate regulations for 1986 model year heavy-duty engines.(2) In addition, oxygen was measured using a Beckman OM-11EA analyzer, exhaust temperature using Type K thermocouples, and exhaust pressures and inlet air depression using manometers and/or Magnehelic gages.

The 1984 transient cycle is described by means of percent of maximum torque and percent of rated speed for each one-second interval, for a test cycle of 1199 seconds duration. This 20-minute transient cycle is composed of four segments of approximately five minutes per segment. The four segments are describes as follows:

Transient Cycle Segment	Time, sec.
New York Non-Freeway (NYNF)	297
Los Angeles Non-Freeway (LANF)	300
Los Angeles Freeway (LAF)	305
New York Non-Freeway (NYNF)	297

In order to generate the transient cycle for governed diesel engines, the engine's full power curve is obtained from an engine speed rpm below idle speed to maximum no-load engine speed. Data from this "power curve," or engine map, are used in conjunction with the specified speed and load percentages to form the transient cycle. A graphic presentation of the speed and torque commands which constitute a transient cycle is given in Figure 1 for illustration purposes.

A transient test consists of a cold-start transient cycle and a hot-start transient cycle. The same engine command cycle is used in both cases. For the cold-start, the diesel engine is operated over a "prep" cycle, then allowed to stand overnight in an ambient soak temperature of 20 to 30°C (68 to 86°F). The cold-start transient cycle begins when the engine is cranked for cold start-up. Upon completion of the cold-start transient cycle, the engine is shut down and allowed to stand for 20 minutes. After this hot soak period, the hot-start cycle begins with engine cranking.

*Superscript numbers in parentheses designate references at end of report.

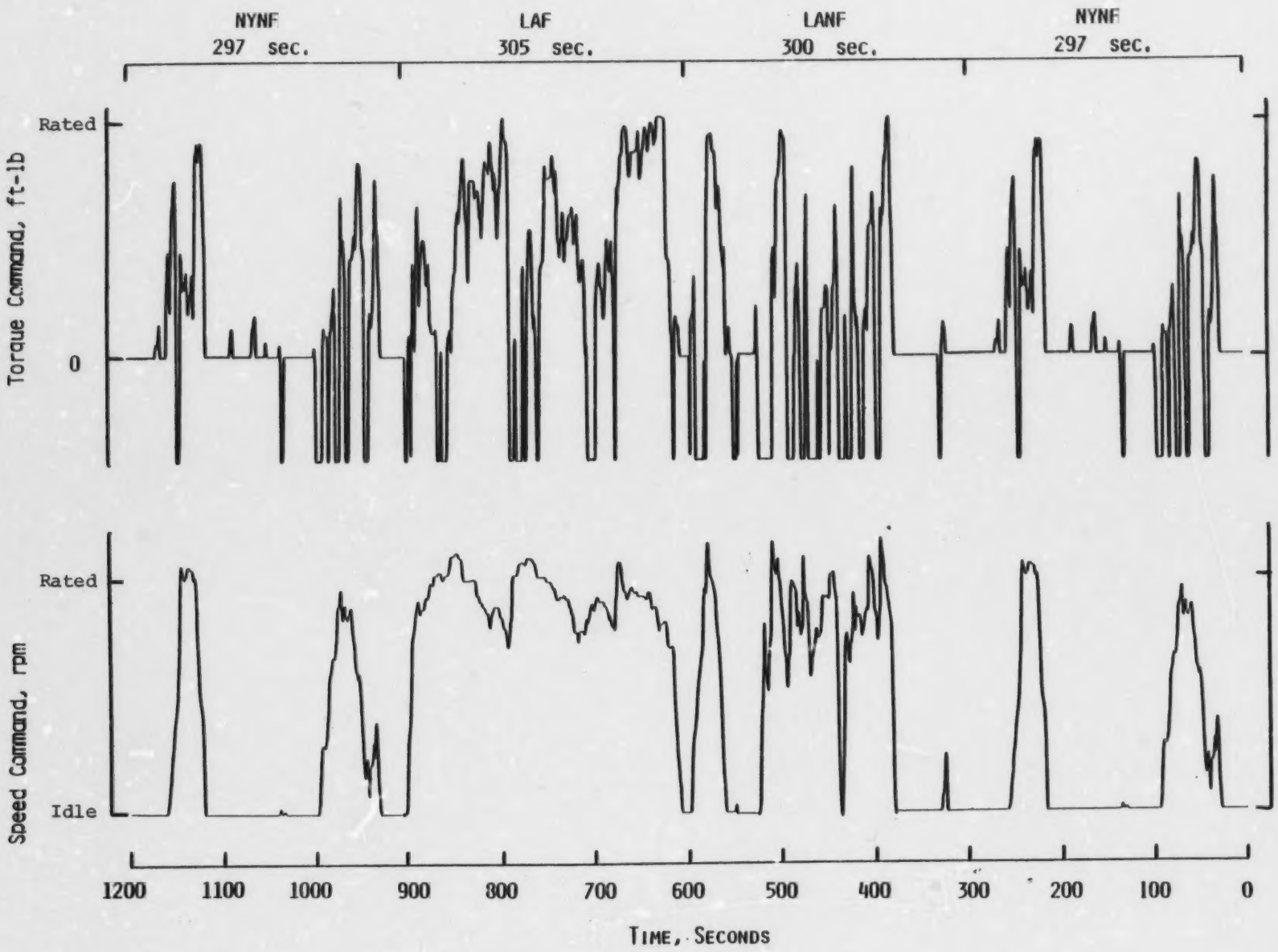


Figure 1. Graphic representation of torque and speed commands for the 1984 Transient FTP cycle for 1984 model year heavy-duty engines

In order to determine how well the engine follows the transient cycle command, engine responses are compared to engine commands and several statistics are computed. The following regression line tolerances should be met:

REGRESSION LINE TOLERANCES

	Speed	Torque	Brake Horsepower
Standard Error of Estimate (SE)	100 rpm	13% of Maximum Engine Torque	8% of Maximum Brake Horsepower
Slope of the Regression Line, M	0.907 - 1.030	0.83-1.03 Hot 0.77-1.03 Cold	0.89-1.03 (Hot) 0.87-1.03 (Cold)
Coefficient of Determination, R^2	0.9700 1/	0.8800 (Hot) 1/ 0.8500 (Cold) 1/	0.9100 1/
Y Intercept of the Regression Line, B	50 rpm	15 ft lb	5.0 brake horsepower

1/ Minimum

In addition to these statistical parameters, the actual cycle work produced should not be more than 5 percent above, or 15 below, the work requested by the command cycle.

If the statistical criteria are not met, then adjustments to throttle servo linkage, torque span points, speed span points, and gain to and from error feedback circuits can be made in order to modify both the engine output (through servo motor control of engine throttle lever) and the dynamometer loading/motoring characteristics. After completion of the cold-start and the hot-start transient cycles, transient composite emission results are computed by the following:

$$\text{Brake Specific Emissions} = \frac{1/7\ (\text{Mass Emission, Cold}) + 6/7\ (\text{Mass Emission, Hot})}{1/7\ (\text{Cycle Work, Cold}) + 6/7\ (\text{Cycle Work, Hot})}$$

III. HEAVY-DUTY VEHICLE EXHAUST MONITORING

Heavy-duty vehicles were being evaluated on a chassis dynamometer under EPA Contract 68-02-3722. For use in this work assignment, exhaust temperature and oxygen content were measured on three of those vehicles under Task 1 of this work assignment. These determinations were made while the vehicle was operating over the chassis version of the heavy-duty transient cycle.[3]

A description of the trucks and a summary of the data are given in Table 2. All data were obtained from locations downstream of the turbocharger. The data for the peak and the "maximum stabilized" temperatures are resummarized as follows:

	Peak Temperature		Max. Stab. Temp.*	
Vehicle	Temp., °C(°F)	O_2, %	Temp., °C(°F)	O_2, %
3-16	425 (800)	8.4	410 (770)	10.0
3-17	470 (880)	6.3	440 (825)	9.5
3-18	440 (825)	8.0	425 (800)	10.0

*Essentially constant condition for about 1.5 minutes

Based on data in the literature (e.g., SAE Papers 810114, 810118, and 830084),[4,5,6] the minimum temperature required to initiate some regeneration of noncatalyzed particulate traps is 540°C (1000°F). "Reliable regeneration" is achieved around 600°C (1100°F). The post-turbocharger exhaust temperatures reached with the three trucks studied over the chassis transient cycle (410 to 440°C for 1.5 minutes) were substantially lower than the 540 to 600°C necessary for regeneration.

Exhaust temperature and oxygen concentration data, obtained by Cummins on an engine similar to the one they provided for use in this work assignment, are included in Figure 2 along with the data generated under Task 1. Exhaust temperature data generated on the chassis dynamometer were in reasonably good agreement with data obtained by Cummins on an engine dynamometer. It should be noted that there is no such thing as actual stabilized operating conditions in the chassis dynamometer transient cycle. Temperatures obtained on the chassis dynamometer appear to be around 20 to 30°C lower than those obtained at Cummins; this difference is in the direction expected.

In summary, exhaust temperatures required for effective regeneration of particulate traps, without using catalysts, were not achieved in post-turbocharger locations during transient operation of these three vehicles. Data were not obtainable in pre-turbocharger locations on the three vehicles, but generally the temperature before the turbocharger is 50 to 100°C higher than the temperature after the turbocharger. Therefore, with a particulate trap located between the engine exhaust manifold and the turbocharger, unassisted regeneration during a transient cycle appeared to be a possibility.

TABLE 2. VEHICLE EXHAUST PARAMETER MEASUREMENTS

Vehicle Number	3-16	3-17	3-18
Vehicle Make	IHC	Kenworth	Ford
Vehicle Model	4300	K100	900
Model Year	1980	1981	1982
GCW, pounds	78,000	80,000	80,000
Transmission Make	Fuller	Eaton	Spicer
Model Number	RT910	RT12509	1107
Engine Make	Cummins	Cummins	Cummins
Model Number	NTC 290	NTC 350	NTC 300
Model Year	1979	1981	1981
Probe A Location from Turbo, cm(in.)[a]	17(6.5)	6(2.5)	11(4.5)
Peak Temperature, °C	425	470	440
Oxygen Vol. % at Peak Temp.	8.4	6.3	8.0
Max. Stab. Temp., °C[b]	410	440	425
Oxygen Vol. % at M.S.T.	10.0	9.5	10.0
Probe B Location from Turbo, cm(in.)	157(62)	91(36)	--
Peak Temperature, °C	395	430	--

[a]Note that probe A location is different for each engine.
[b]Approximate average over 1.5 minutes of operation.

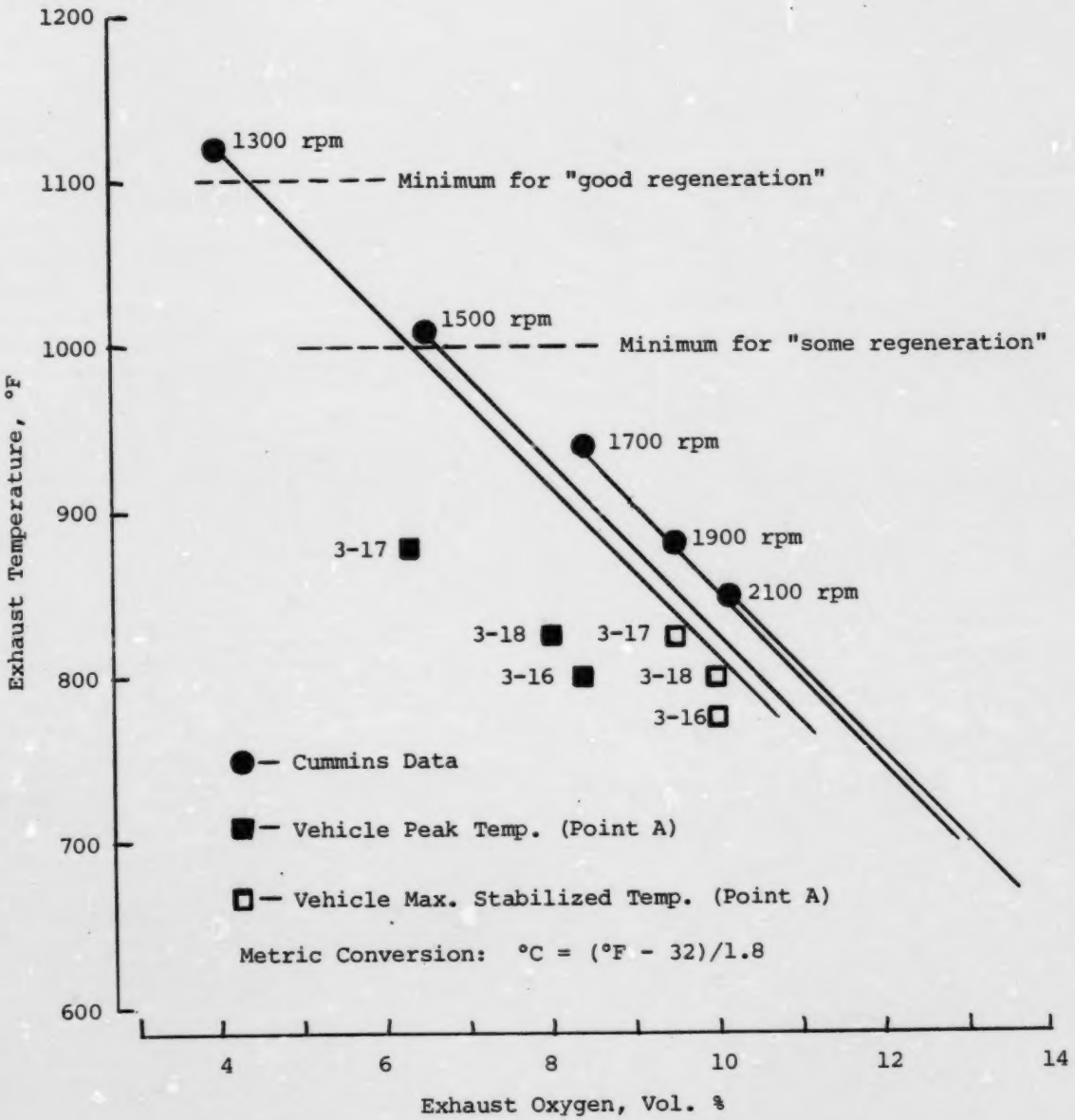


Figure 2. Exhaust temperature and oxygen concentration data

IV. ENGINE BASELINE EVALUATIONS

Transient and steady-state evaluations of the Cummins NTC-400 engine were conducted with primary emphasis on obtaining definition of attainable exhaust temperatures. The evaluations were conducted in accord with stated requirements, while taking into account the capabilities of the available test cell.

Transient cycle test results are summarized in Tables 3 and 4, and the computer printouts are in Appendix A. The highest exhaust temperature observed for longer than a few seconds during the transient cycle was 530°C (985°F). This temperature was attained in the exhaust manifold prior to the turbocharger. Maximum temperature subsequent to the turbocharger was 380°C (715°F), and, as indicated by these data, insulating the exhaust manifold did not have a significant effect.

TABLE 3. TRANSIENT CYCLE TEST RESULTS
Cummins NTC-400 (CPL531)

Test	Cycle	Emissions, g/*				BSFC, lb/*	Work, *
		HC	CO	CO_2	NO_x		
		English Units (* = hp-hr)					
BL-1	Cold	1.03	3.39	644	5.77	0.452	25.2
BL-2	Cold	1.02	3.80	654	6.58	0.462	25.6
Avg.	Cold	1.03	3.6	651	6.2	0.46	25.4
BL-0	Hot	0.38	2.70	595	6.21	0.416	26.7
INS-0[a]	Hot	0.44	2.75	594	6.41	0.415	26.5
Avg.	Hot	0.41	2.7	595	6.3	0.42	26.6
Composite		0.50	2.8	603	6.3	0.42	26.4
		Metric Units (* = kW-hr)					
BL-1	Cold	1.38	4.55	864	7.74	0.275	18.78
BL-2	Cold	1.37	5.10	883	8.82	0.281	19.08
Avg.	Cold	1.38	4.83	874	8.28	0.278	18.93
BL-0	Hot	0.50	3.62	797	8.33	0.253	19.87
INS-0[a]	Hot	0.59	3.69	797	8.59	0.253	19.76
Avg.	Hot	0.55	3.66	797	8.46	0.253	19.82
Composite		0.67	3.83	808	8.43	0.257	19.69

[a]Insulated exhaust manifold

TABLE 4. TEMPERATURES DURING TRANSIENT CYCLE TEST

Test	Cycle	Maximum Temperature, °C(°F) Pre-Turbo Momentary	Pre-Turbo Stabilized[a]	Two Feet Post-Turbo Momentary	Two Feet Post-Turbo Stabilized[b]
BL-1	Cold	560	520	380	380
BL-0	Hot	560	530	390	380
INS-0[c]	Hot	560	530	390	380
BL-1	Cold	(1040)	(970)	(715)	(715)
BL-0	Hot	(1040)	(985)	(735)	(715)
INS-0[a]	Hot	(1040)	(985)	(735)	(715)

[a]For about 40 seconds (above 11 percent oxygen by volume)
[b]For about 20 seconds
[c]Insulated exhaust manifold

In the transient cycle, most of the non-idle operation appears to be high-speed with relatively low power. The approximate breakdown of the transient cycle is as follows:

Idle	40%
Cut Throttle	15%
Other	45%

Of the 60% at Speeds Greater than Idle:

Speed Greater than 70% of Rated	45%
Speed Greater than 80% of Rated	35%
Speed Greater than 90% of Rated	20%

Of the 45% with Torque Greater than Zero:

Torque Greater than 30% of Rated	30%
Torque Greater than 60% of Rated	15%
Torque Greater than 90% of Rated	10%

The maximum power condition maintained for an extended period of time is about 80 percent of rated torque at 90 percent of rated speed.

Therefore, with the exception of idle, there appears to be relatively little low-speed operation. In addition, there appears to be relatively little high-torque operation. The torque level has significant effect on exhaust temperature, with higher torque producing higher temperatures.

This NTC-400 engine had the highest power output of any engine evaluated to date over the transient cycle in this laboratory. Difficulties were encountered in getting through the transient cycle due to repeated blowing of a fuse in the dynamometer control circuitry at some point in the cycle. The cycle statistics could not be met. These factors were not considered to have a significant effect on exhaust temperatures, but could have some effect on emissions. The dynamometer control system in this test cell was modified prior to the subsequent evaluations with the particulate traps.

Data obtained during the steady-state evaluations of this engine in its standard configuration are included in Appendix A. The exhaust temperature and oxygen concentration data are considered to be of primary importance, and these data are presented in graphic form in Figure 3. The highest before-the-turbocharger exhaust temperature was obtained at maximum power at an engine speed of 1100 rpm. Attainable temperatures decreased with increases or decreases in engine speed from the 1100 rpm. Temperatures that would provide assured regeneration were obtainable at engines speed between 900 and 1500 rpm.

Data were also received from Cummins on an engine of the same model. The data associated with the maximum exhaust temperature at each engine speed evaluated are summarized as follows:

RPM	HP	A/F Ratio	Exh. (Stack) Temp., °C(°F)	Exh. Oxygen Conc., %
1300	309	18.8	603 (1118)	4.0
1500	347	22.4	543 (1009)	6.6
1700	375	25.6	504 (940)	8.4
1900	400	28.2	474 (886)	9.4
2100	400	30.3	457 (854)	10.2
Min. for Regeneration			600 (1110)	3

These data generally agree with the data developed in this work assignment.

Data for equivalent air-fuel ratio conditions of approximately 31.5 are summarized as follows:

Ratio	RPM	HP	Exh. Stack Temp., °C	Exh. O_2 Conc., %	Max. HP	HP/ Max. HP
31.6	1300	123	413	10.7	309	30%
31.1	1700	225	442	10.5	375	60%
31.6	2100	359	440	10.7	400	90%

Exhaust temperature was primarily a function of the air-fuel ratio, with power output having only a relatively minor effect.

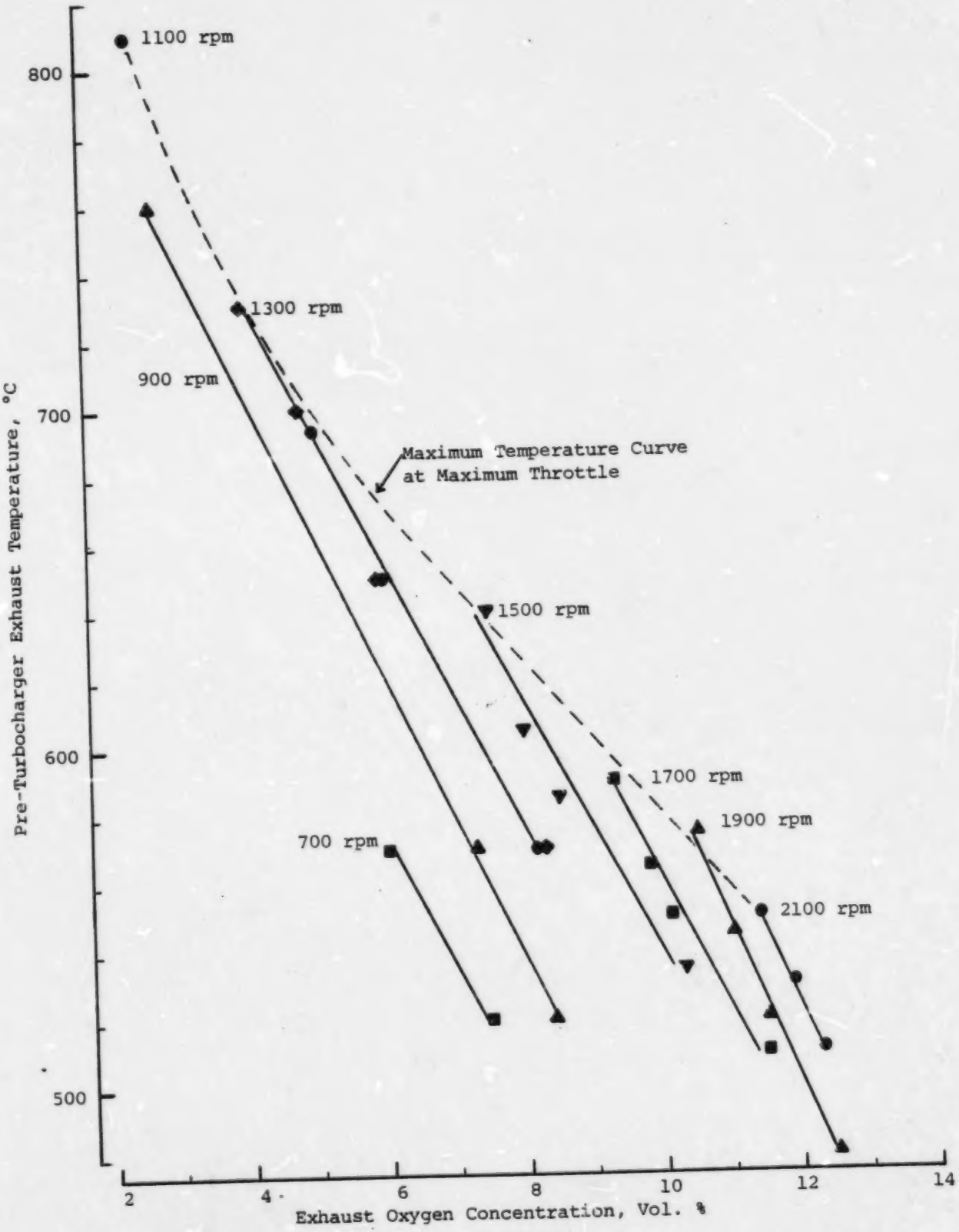


Figure 3. Pre-turbo exhaust temperature vs oxygen from map of Cummins NTC-400 (CPL531)

Exhaust temperature and oxygen concentration data, with the intake restricted to the maximum possible without resulting in turbocharger surge, are summarized in Appendix A-9. With this amount of intake restriction, the maximum temperature during the transient cycle should be around 610°C. Of course, this amount of intake restriction would probably only be applicable to barometric pressures equal to or higher than the barometric pressure at San Antonio (i.e., only at altitudes below 600 feet).

Relative to insulating the exhaust system, it appears that insulation is not critical relative to the exhaust manifold and/or the exhaust pipe. The effect of insulating the turbocharger was not determined at that time, but it was considered doubtful that insulation would have a major effect during transient operation. At the transient cycle operating condition producing maximum exhaust temperature, the temperature drop in the exhaust manifold was determined to be negligible. At that same operating condition, the temperature drop in two feet of exhaust tubing was only about 5°C (9°F).

In summary, the maximum temperature normally attained in the exhaust system (i.e., obtained during the transient cycle) of the NTC-400 engine was considered to be marginal for regeneration of the particulate trap. Operating conditions existed with this engine, however, such as high power at low to moderate engine speeds, at which regeneration could be assured.

V. PARTICULATE TRAP BYPASS SYSTEM

A primary purpose of this work assignment was evaluation of the concept of particulate trap bypass. In the event that the trap becomes loaded with particulate (i.e., due to operation under conditions not producing the temperatures necessary for regeneration), automatic bypass of the trap would occur until temperature conditions for regeneration are attained in the exhaust.

Bypass Design Considerations

Considerable thought was given to the design of a bypass/regeneration system, including a brainstorming session and several discussions with the EPA Branch Technical Representative. Some of the findings, ideas, and tentative conclusions are discussed as follows:

The following is based on relatively frequent operation at, or near, wide-open-throttle and governed engine speed. Vehicle operating modes under which this condition is expected to occur are: accelerating through the gears in urban operation, and passing or hill-climbing on the highway. This condition occurs in both the engine dynamometer and the chassis dynamometer transient cycles developed by the EPA.

With the foregoing operating assumption, the exhaust backpressure on the engine side of the particulate trap can be used to determine a need for bypass of the trap. When the exhaust backpressure reaches some selected value, the bypass valve would be actuated. The only operation foreseen during which this control method would be inappropriate was that by a very "light-footed," "slow-speed" driver (such a driver was considered to be rare or non-existent with the classes of heavy-duty vehicles being considered in this project). Therefore, it appeared that a relatively simple method existed for determining when to bypass.

Control parameters for regeneration and for deactivation of bypass, however, do not appear to be as straightforward, unless the conditions for regeneration frequency occur for relatively long periods of time during normal operation of the vehicle. If regeneration temperature were to occur frequently during normal operation, exhaust temperature could be used as the criteria for when to deactivate a bypass condition.

If a supplemental method is required to achieve regeneration, the criteria for deactivation of the bypass condition will likely be effected by the criteria used for activation of regeneration. The same parameter(s) used to actuate the regeneration system should also be applicable for deactivation of the bypass. It appears likely that exhaust temperature would be the parameter used, or at least one of the parameters used.

Another consideration was minimization of temperature shock to the trap upon deactivation of bypass. Several methods were considered for reducing temperature shock, but it was subsequently determined that temperature shock was not a significant problem.

The primary concern with this system was the same as that for any other trap system, that is, protection against destructive regeneration. The best protection against destructive regeneration appears to be frequent regeneration, to assure that the particulate does not build up to potentially destructive amounts. One approach would be to set the bypass control parameter at a level which will restrict the trap loading to an amount that could not produce a destructive regeneration. The practicability of such an approach, however, has not been established. Again, the regeneration method used appeared to be an important consideration affecting the selection of the parameters for deactivation of bypass.

A basic design for a bypass system was developed, and that system is illustrated in Figure 4. This design was based on the following:

- Use of a high efficiency trap
- Periodically attaining conditions necessary for regeneration
- Application of relatively simple, inexpensive components
- System fails in a through-the-trap exhaust flow configuration

This system was designed to function in the following manner. The trap collects particulate until regeneration occurs, or until the backpressure during WOT acceleration is sufficiently high to actuate the pressure switch. When the backpressure is sufficiently high to actuate the pressure switch, the exhaust is switched to and remains in bypass. When the trap inlet temperature is sufficiently high to actuate the temperature switch, the exhaust again flows through the trap. If the trap exit temperature becomes excessive, the exhaust flow is switched to bypass until the exit temperature decreases to some predetermined acceptable temperature.

Other criteria could result in major changes in the design of a bypass system. If conditions for regeneration are not periodically attained, provisions would be required to assist attaining such conditions. If unassisted regeneration can not be attained, it would appear that the potential benefits of bypass would be greatly reduced. If large reductions in trapping efficiency become allowable, external bypass may not be necessary (e.g., some early low-efficiency wire-mesh traps were difficult to plug). Attaining regeneration temperature, without special operational provisions, could require the use of traps in the exhaust manifold. Application of manifold traps could greatly affect the bypass criteria.

Internal Bypass - Another possible approach is the use of internal bypass (e.g., a wall-flow ceramic trap with a controlled number of unplugged cells). This approach was analyzed briefly, but was not actually considered for use in this work assignment. A very brief mathematical analysis was made to estimate the potential for internal bypass. Since the mathematics for such determination are extremely complex, estimation techniques were used. The results obtained are considered to be illustrative of results which could be attained using internal bypass within the trap. The basis for the numbers used was the experience with a Corning trap used on a light-duty vehicle in previous

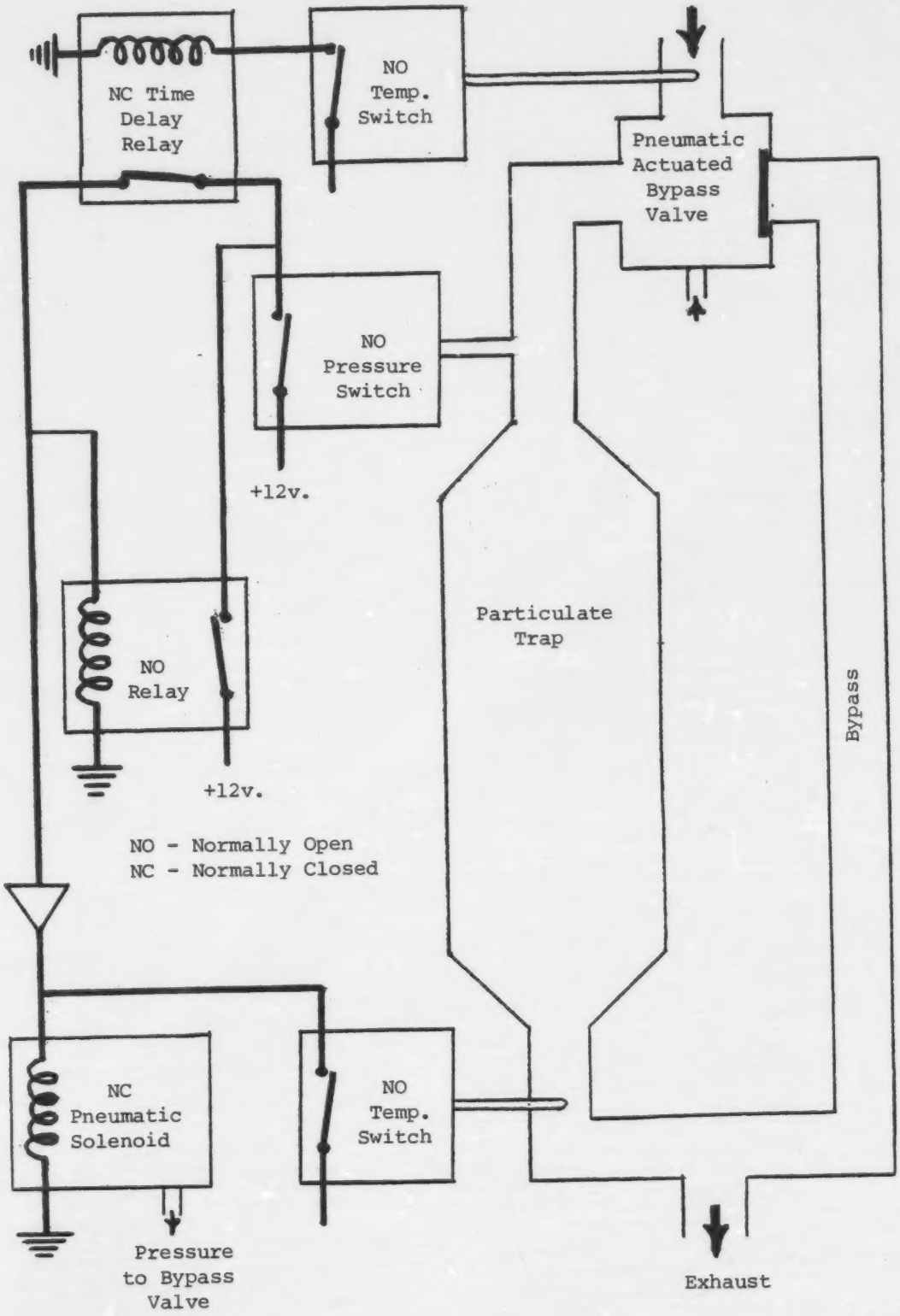
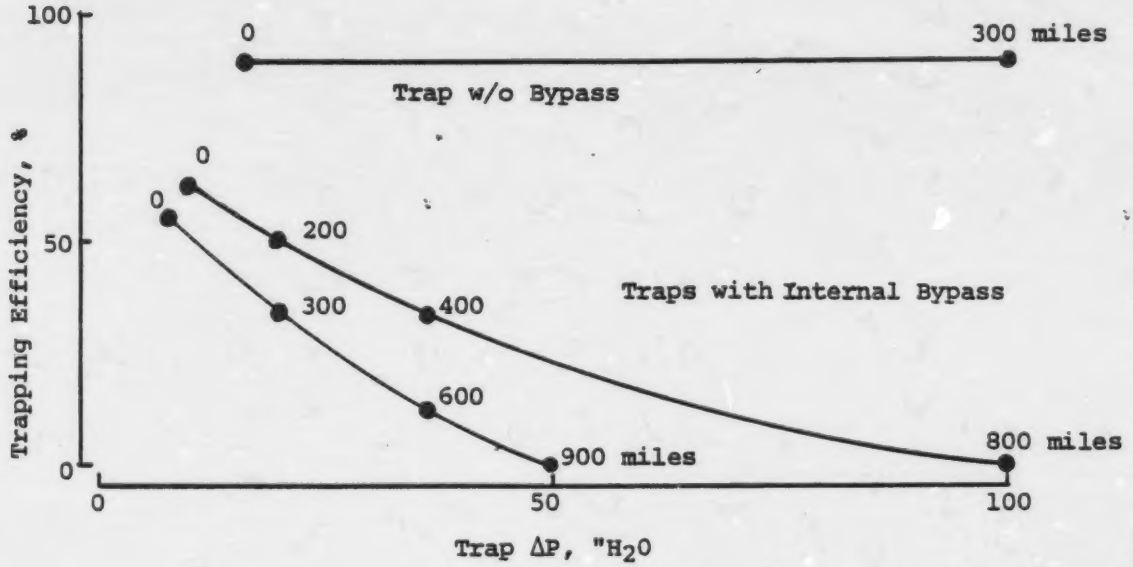


Figure 4. Schematic of a potential particulate trap bypass system

EPA Contract 68-03-2873.(6) The results of the brief analysis are summarized in the following illustration:



Based on the results obtained from this brief analysis, it appears that internal bypass might be applicable if the decrease in trapping efficiency is acceptable. There are, however, a couple of unknowns concerning internal bypass. One is the large differences in flow velocity across the inlet of the trap: one or two orders of magnitude higher flow velocity through the unplugged cells. This could result in a decrease in overall trapping efficiency from that calculated on the basis of percent of exhaust flow. Another unknown concerns regeneration, especially if such a trap with internal bypass were to become completely filled with particulate in all except the unplugged cells.

In looking at the pros, cons, and unknowns concerning internal bypass, it appears that the concept could be worthy of some consideration if low trapping efficiency is acceptable if low trapping efficiency is acceptable. Wire wool and ceramic foam traps might also be amenable to a form of internal bypass. In fact, some of the early, less efficient wire wool traps were difficult to plug past some point.

Bypass System - The bypass system shown in previous Figure 4 was assembled for use in this work assignment. A "breadboard" type system was built using available and/or readily obtainable components. The purpose of this system was to evaluate "proof of concept." A schematic showing the components used is included in Appendix B.

This system was found to function basically as designed (i.e., it would bypass at the set pressure, and would deactivate the bypass at the set temperature). It did appear, however, that differential pressure across the particulate trap might be a better criterion to use, rather than the inlet pressure to the trap. The bypass valve was mounted between the exhaust manifold and the turbocharger. Under some steady-state operating conditions, the bypass valve experienced temperatures of up to 800°C. This valve, which was an existing unit that had previously been used in a post turbocharger application, was found to be inadequate for long term operation in a pre-turbocharger environment. This fact, however, did not have a major effect on the determination of "proof of concept" for a particulate trap bypass system.

Bypass Operational Considerations - The bypass system was designed to function without the use of logic circuitry. Bypass is deactivated when the exhaust reaches a set temperature. Regeneration of the trap then requires that this exhaust temperature be maintained until the trap is heated; a number of minutes is required to bring a cold particulate trap up to temperature. In the transient cycle, a high exhaust temperature is not maintained for a sufficiently long period of time to enable bringing a cold particulate trap up to a temperature necessary for regeneration.

A trap with a large build-up of particulate is a potential candidate for a destructive regeneration. A simple bypass control, such as applied in this work assignment, assumes frequent occurrence of engine operating conditions which will provide sufficient backpressure with a loaded trap to actuate the bypass. If such operating conditions do not occur in some vehicle applications, a high loading of particulate can occur on the particulate trap before actuation to bypass occurs. If conditions necessary for regeneration are not attained, deactivation of bypass might never occur. Designing around such potential situations requires a more complicated control system.

Engine performance, primarily under transient operation, is better with the exhaust going through a non-restricting, short-coupled bypass than when exhaust goes through a "high mass" particulate trap. It would appear that such a situation could be conducive to tampering, and that system design should be such that engine performance with exhaust through the trap should be equal to or better than performance with the exhaust through bypass.

In general, it appears that design of a bypass system with simple controls is dependent on occurrence of engine operation producing extended periods with exhaust temperatures sufficient for regeneration. Such modes of engine operation do not exist in the transient cycle. If it is necessary to provide a means of producing such modes of operation, it may be as well to incorporate a means of frequently providing increased exhaust temperatures to produce regeneration, and could eliminate a need for bypass.

VI. EVALUATION OF PARTICULATE TRAPS AND BYPASS SYSTEM

In addition to evaluating bypass of particulate traps, another primary purpose of this work assignment was to determine if regeneration could be obtained during operation over the transient cycle. Other areas studied were the effect on engine performance and the particulate removal efficiency of the particulate traps.

Exhaust configurations included: dual Corning particulate traps and a bypass system mounted between the engine exhaust manifold and the turbocharger; a single Corning particulate trap close-coupled between the exhaust manifold and turbocharger; and a Johnson Matthey particulate trap mounted as close as practical to the exhaust outlet of the turbocharger. In addition, an evaluation was conducted with a straight section of tubing replacing the dual Corning traps.

A. Summary and Discussion of the Results

The average results of hot-start emissions evaluations are summarized in Table 5 and are shown graphically in Figure 5. The order of presentation on the figure is based on work produced over the transient cycle.

With either the single or dual Corning particulate traps, exhaust particulate in the hot-start tests was reduced by eighty to eighty-five percent. With the Johnson Matthey trap, particulates were reduced by about fifty percent. In the bypass mode, and with the two Corning traps replaced with a straight section of tubing, particulates increased over baseline values by about thirty-five and forty-five percent, respectively.

TABLE 5. AVERAGE RESULTS FOR HOT-START TRANSIENT TESTS

Tests	Configuration	HC	CO	CO_2	NO_x	Part.	BSFC, lb/hp-hr	Work, hp-hr
--	Initial Baseline	0.4	2.7	595	6.3	--	0.42	26.5
BLWO	In Bypass Mode	0.5	4.2	575	5.7	0.54	0.40	24.5
BLWT	Two Corning Traps[a]	0.5	5.5	630	5.2	0.07	0.44	20.0
BLDT	Dummy Trap	0.5	4.5	565	5.2	0.59	0.40	24.0
TBL	Baseline Check	0.6	3.4	560	6.0	0.42	0.39	26.0
BLST	One Corning Trap	0.5	5.1	580	5.4	0.07	0.41	23.0
JM	JM Trap	0.1	3.7	575	6.0	0.21	0.40	25.5
FBL	Final Baseline	0.5	3.4	575	6.5	0.39	0.40	25.0

[a]In parallel.

In general, CO increased and NO_x decreased with decrease in work produced over the cycle. HC remained essentially unchanged, except for a significant decrease with the trap from Johnson Matthey. Fuel consumption increased with the more major decreases in cycle work.

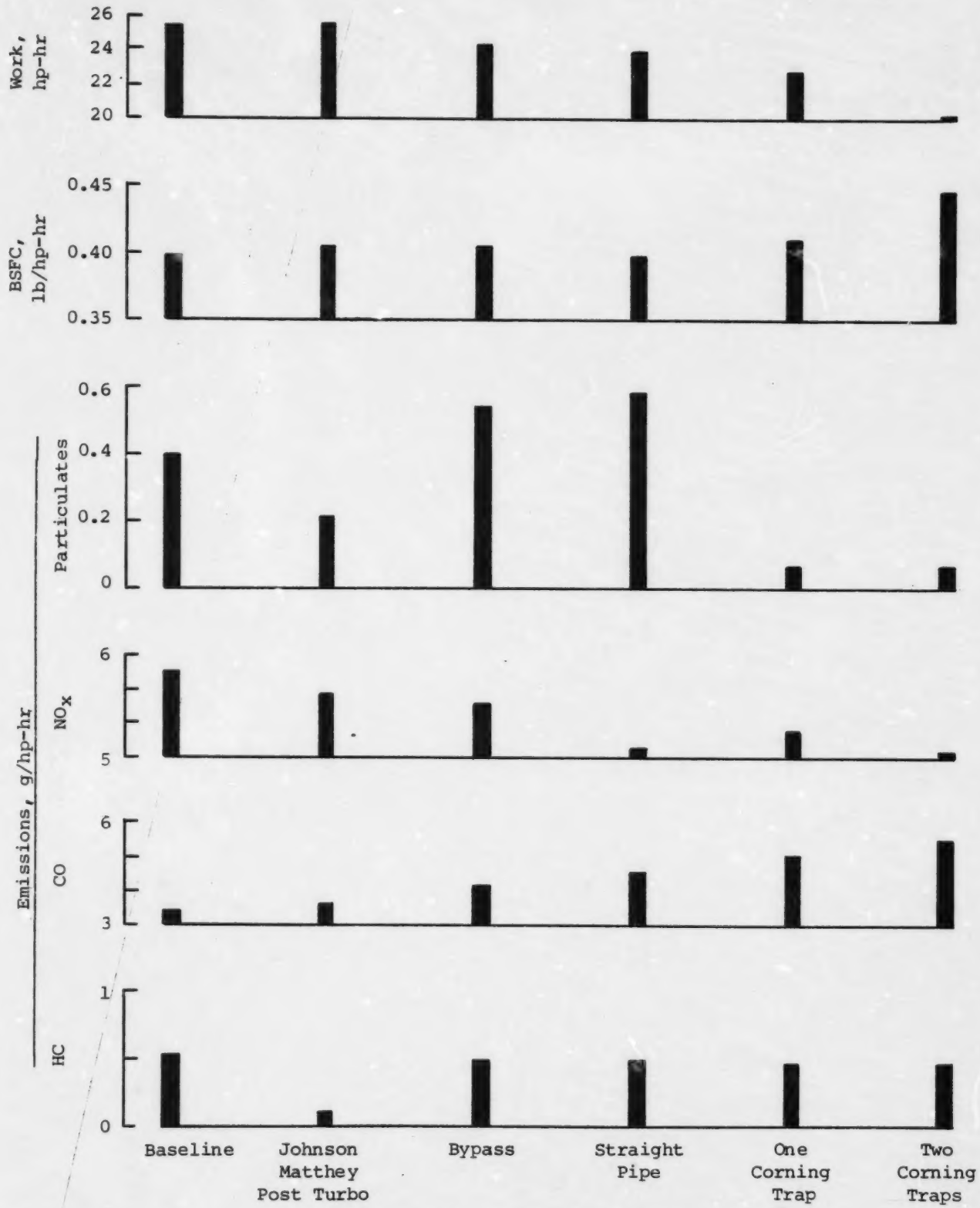
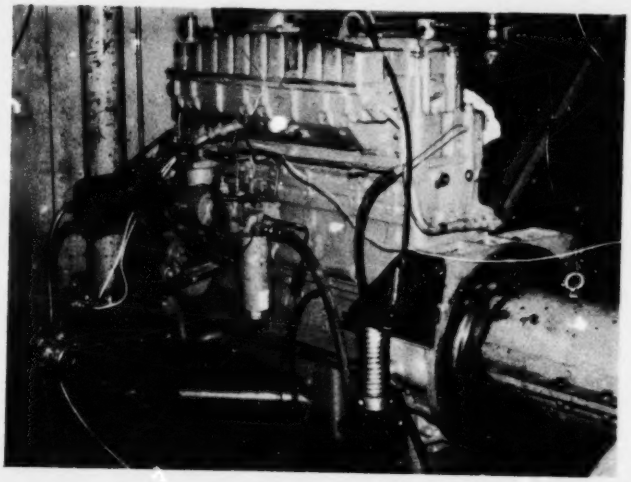
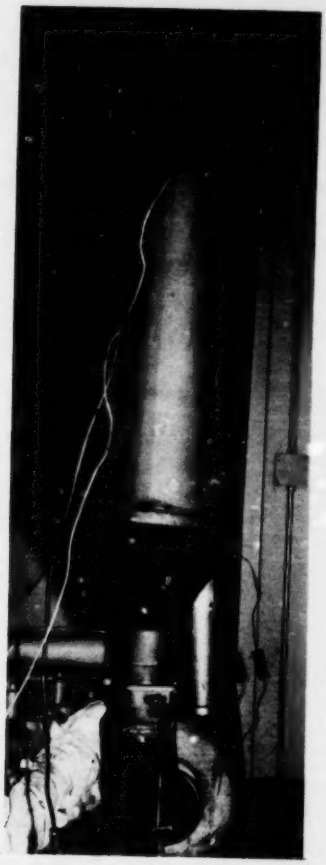


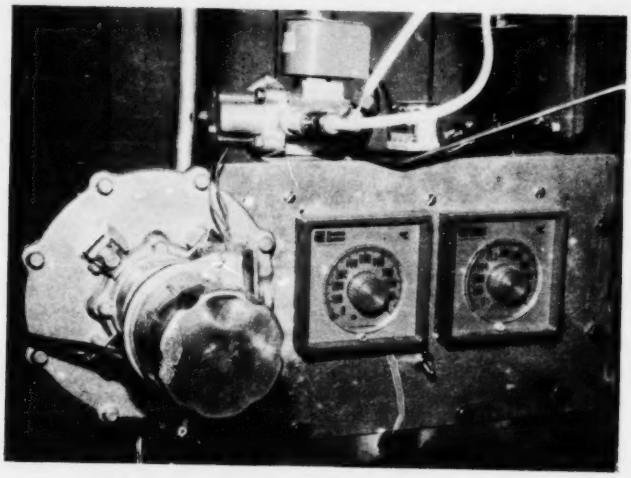
Figure 5. Graphical presentation of the results for hot-start transient test



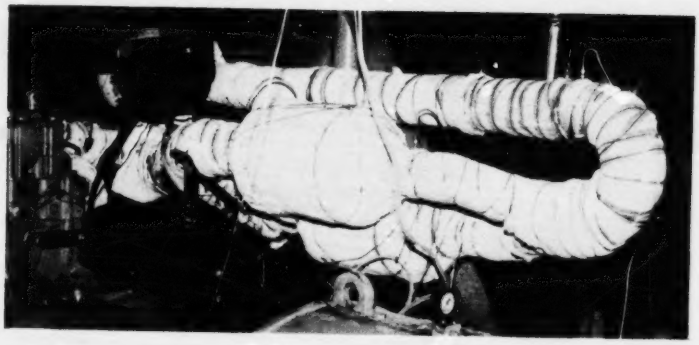
Cummins NTC-400 Engine with Bypass Control System



Johnson Matthey Particulate Trap



Particulate Trap Bypass Control System



System with Two Corning Filters and a Bypass System

Figure 6. Views of the engine, bypass system controls, and particulate trap installations

The amount of turbocharging is affected by the mass flow rate and the density of the exhaust gases. Addition of particulate traps, or just additional tubing, between the exhaust manifold and the turbocharger results in a "heat sink" and in heat losses due to conduction/convection. Loss in exhaust gas temperature results in decreased turbocharger effectiveness. In addition, any increase in exhaust backpressure reduces the amount of exhaust flow, which decreases the amount of turbocharger boost. In the configurations evaluated, the effect of the temperature drop with pre-turbocharger mounted configurations appeared to be the primary factor affecting engine performance.

With one or more particulate traps mounted prior to the turbocharger, cold-start operation was significantly affected. Power output was reduced until the exhaust system was thoroughly warmed-up; warm-up required as long as several minutes.

Without the use of carbon catalysts, a temperature of approximately 600°C, or greater, is required for regeneration of the particulate trap. Without "relatively drastic" reduction in intake air flow, post-turbocharger temperatures of 600°C were found to be unattainable during "normal operating conditions." Prior to the turbocharger, however, exhaust temperatures above 600°C occur even during operation over the transient cycle; but such temperatures occur for only short periods of time. With one Corning particulate trap mounted close-coupled to the exhaust manifold, some regeneration of the trap occurred during operation over the transient cycle. By appropriate reduction in air flow to the engine, conditions for regeneration could be readily achieved with a single Corning particulate trap close-coupled to the exhaust manifold. By design optimization of the particulate trap system parameters (e.g., system mass, heat losses, and flow restriction) it appears that significant improvements could be achieved in the results obtained in these rather cursory evaluations.

B. Results of Steady-State Evaluations

Steady-state evaluations were conducted over a range of engine operating speeds from near idle speed to governed speed. These evaluations included operation at the "standard" intake restriction of 50 centimeters (20 inches) of water column at 2100 rpm with maximum power, and operation with the maximum intake restriction that did not result in occurrence of turbocharger surge under some engine operating conditions. Results of these evaluations are given in Appendix A-5 through A-9, and are summarized briefly in Tables 6 and 7.

From the data in Table 6, temperatures necessary for particulate trap regeneration occur with maximum throttle at the lower engine speeds. Such engine speeds, however, are not prevalent in the transient cycles for operation on the engine or the chassis dynamometers. With maximum intake restriction, as reported in Table 7, exhaust temperatures were significantly increased at higher engine speeds. The intake restriction used in these evaluations, however, would only be applicable at altitudes between sea level and 600 feet. Additional intake restriction could be applied at the higher engine speeds, provided means were applied to assure immediate decrease in intake restriction at lower engine speeds.

TABLE 6. SUMMARY OF THE STEADY-STATE EVALUATIONS AT MAXIMUM TORQUE

Cummins NTC-400 (CPL531)
Intake Restriction Set at 20" H_20 at 2100 rpm

Speed, rpm	Torque, ft-lbs	BSFC, lb/hp-hr	Exhaust Temp., °C		Exhaust Oxygen % by Vol.
			Pre-Turbo	Post-Turbo[a]	
700	655	0.44	570	485	6.0
900	1080	0.47	760	730	2.7
1100	1245	0.38	810	710	2.4
1300	1280	0.36	730	640	4.0
1500	1230	0.35	640	545	7.5
1700	1165	0.33	590	490	9.3
1900	1090	0.35	575	455	10.5
2100	995	0.36	550	435	11.4

Speed, rpm	Torque, ft-lbs	Undiluted Exhaust Emissions			
		HC, ppmC	CO, ppm	CO_2, %	NO_x, ppm
1300	1280	44	3578	11.1	1935
1500	1230	83	776	9.3	2055
1700	1165	75	266	8.1	1905
1900	1090	63	146	7.4	1710
2100	995	62	106	6.8	1470

Speed, rpm	Torque, ft-lbs	Emissions, g/hp-hr					BSFC[b]	
		HC	CO	CO_2	NO_x	Part.	Meas.	Calc.
900	1130	0.12	7.7	629	6.3	1.27	0.442	0.444
1700	1165	0.15	0.8	470	10.6	0.10	0.337	0.326
1900	1085	0.14	0.5	475	10.2	0.14	0.343	0.330
2100	1000	0.15	0.4	497	10.2	0.13	0.349	0.345

[a]Measured two feet from exhaust outlet of the turbocharger.
[b]Measured using measured fuel consumption, and calculated using the "carbon balance" method.

TABLE 7. MAXIMUM TORQUE STEADY-STATE EVALUATIONS AT MAXIMUM INTAKE RESTRICTION
Cummins NTC-400 (CPL 531)
Intake Restriction Set at 73" H_2O at 2100 rpm[a]

Speed, rpm	Torque, ft-lbs	Exhaust Temp., °C		Exhaust Oxygen, % by Vol.	Exhaust Temp., °C Max. - Std. Res.[c]	
		Pre-Turbo	Post-Turbo[b]		Pre-Turbo	Post-Turbo[b]
700	650	580	495	5.8	10	10
900	1020	750	655	2.9	-10	25
1100	1226	820	730	2.2	10	20
1300	1260	820	695	2.4	90	55
1500	1230	685	590	6.5	45	45
1700	1165	680	545	7.1	90	55
1900	1095	640	530	9.0	65	75
2100	1005	645	525	9.4	95	90

[a]Maximum restriction that does not result in turbocharger surge at some engine operating condition (not necessarily at rated speed and load).
[b]Measured two feet from exhaust outlet of the turbocharger.
[c]Difference between the temperatures with maximum intake restriction and with standard intake restriction.

In summary, engine operating conditions exist that provide the exhaust temperatures necessary for regeneration of particulate traps. To enable taking maximum advantage of such conditions, however, would require development of a control system. Such a system could be significantly more complicated than the simple control system desired for use in this work assignment. Under normal operating conditions and configurations of the NTC-400 engine, exhaust temperatures high enough to provide potential for particulate trap regeneration occurred only in locations prior to the turbocharger.

C. Emissions Results of Transient Cycle Evaluations

Transient cycle evaluations were conducted in three configurations with exhaust particulate traps and in three configurations without particulate traps. Results of those evaluations are included in Appendix C and are summarized in subsequent tables included in this section of the report.

Several of the exhaust system configurations evaluated are shown in Figure 6. The configuration with two Corning particulate traps included a bypass valve, and the entire system was installed between the engine exhaust manifold and the turbocharger. The single Corning particulate trap was close-

coupled to the exhaust manifold and the turbocharger to minimize system mass and surface area; the bypass system was omitted. The Johnson Matthey particulate trap was installed after the turbocharger. The other test configurations included the standard engine configuration, replacement of the two Corning traps with a single section of exhaust tubing (dummy trap), and the bypass system operating in the bypass mode.

Results of the transient cycle emissions evaluations are summarized in Tables 8 and 9, and are presented graphically in previous Figure 5. The hot-start test accounts for 6/7 of the total composite value, and is therefore of primary importance for all emissions, with the possible exception of HC. In Figure 5, the data are presented in an order based on the work produced during the cycle. The loss in cycle work in these evaluations appears to be primarily a function of the total mass and surface area that was installed into the system between the engine exhaust manifold and the turbocharger. For the baseline and Johnson Matthey trap in a post-turbocharger location, the turbocharger was mounted directly onto the exhaust manifold. With the other four configurations evaluated, the mass installed between the exhaust manifold increases from left to right on Figure 5 (i.e., the two Corning traps represent the maximum mass configuration).

In general, CO increased and NO_x decreased with a decrease in work produced over the cycle. HC did not appear to be affected by exhaust system configuration, other than the reduction with the catalyzed Johnson Matthey particulate trap. Particulates produced by the engine increased with an increase in cycle work (i.e., bypass and straight pipe configurations). Relative to baseline particulates, the Corning trap(s) provided about an 85 percent reduction and the Johnson Matthey trap provided about a fifty percent reduction. Relative to the particulate production of the engine with the Corning particulate trap(s) installed, the reduction in particulates was probably somewhat greater than 85 percent (e.g., Corning trap relative to the bypass and straight pipe). Fuel consumption (i.e., BSFC) increased with the relatively large reductions in cycle work (i.e., one and two Corning traps).

D. Effect of Configurations on Engine Performance

Although evaluation of engine performance was not a direct requirement in this work assignment, several observations regarding engine performance appear to be of potential importance. However, no methods are known to be available for directly relating these observations on the engine dynamometer to vehicle driveability.

One factor is the effect of mass between the exhaust manifold and the turbocharger on the time required to obtain effective operation of the turbocharger. Another is the delay in turbocharger reaction during transient operation. It is felt that by appropriate control of system design parameters the effects on engine performance can be minimized; this is illustrated by the improvement obtained with one Corning trap, compared with the results using two traps. It appears that system mass and surface area have more effect than the associated system resistance to exhaust flow.

TABLE 8. SUMMARY OF RESULTS FOR HOT-START TRANSIENT TESTS

Test	Configuration	Emissions, g/hp-hr					BSFC, lb/hp-hr	Work, hp-hr
		HC	CO	CO_2	NO_x	Part.		
BL-0	Initial Baseline	0.38	2.70	595	6.21	--	0.416	26.7
INS-0	Initial Baseline	0.44	2.75	594	6.41	--	0.415	26.5
	Average	0.4	2.7	595	6.3	--	0.42	26.6
BLW03	In Bypass Mode	0.54	4.20	579	5.86	0.55	0.407	23.9
BLW04	In Bypass Mode	0.50	4.15	579	6.04	0.52	0.407	24.4
BLW05	In Bypass Mode	0.54	4.43	569	5.54	0.57	0.400	25.2
BLW06	In Bypass Mode	0.51	3.95	571	5.49	0.54	0.401	24.1
	Average	0.5	4.2	575	5.7	0.54	0.40	24.5
BLWT1	Two Corning Traps[a]	0.46	5.48	640	5.04	0.07	0.450	19.8
BLWT2	Two Corning Traps[a]	0.41	5.49	624	5.20	0.06	0.439	20.0
BLWT3	Two Corning Traps[a]	0.49	5.54	641	5.21	0.08	0.451	20.0
BLWT4	Two Corning Traps[a]	0.52	5.36	620	5.15	0.08	0.436	20.4
	Average	0.5	5.5	630	5.2	0.07	0.44	20.0
BLDT2	Dummy Trap	0.51	4.52	564	5.22	0.59	0.397	23.9
RBL2	Baseline Check	0.56	3.44	560	6.02	0.42	0.393	25.8
BLST1	One Corning Trap	0.49	5.21	595	5.54	0.07	0.419	22.3
BLST2	One Corning Trap	0.43	5.01	567	5.34	0.06	0.399	23.4
	Average	0.5	5.1	580	5.4	0.07	0.41	23.0
JMBL1	JM Trap	0.09	3.50	573	5.71	0.20	0.401	25.5
JMBL2	JM Trap	0.08	3.59	577	6.00	0.19	0.403	25.5
JMLT1	JM Trap Loaded	0.04	3.69	574	6.00	0.22	0.402	25.5
JMLT2	JM Trap Loaded	0.06	4.08	579	6.08	0.24	0.405	25.2
	Average	0.07	3.7	575	6.0	0.21	0.40	25.5
FBL1	Final Baseline	0.50	3.52	578	6.51	0.40	0.405	25.2
FBL2	Final Baseline	0.50	3.33	572	6.51	0.38	0.401	25.2
	Average	0.5	3.4	575	6.5	0.39	0.40	25.0

[a]In parallel.

TABLE 9. SUMMARY OF RESULTS FOR COLD-START TRANSIENT TESTS

Test	Configuration	Emissions, g/hp-hr HC	CO	CO_2	NO_x	Part.	BSFC, lb/hp-hr	Work, hp-hr
BL-1	Initial Baseline	1.03	3.39	644	5.77	0.60	0.452	25.2
BL-2	Initial Baseline	1.02	3.80	654	6.58	0.54	0.462	25.6
	Average	1.0	3.6	650	6.2	0.57	0.46	25.5
BLW01	In Bypass Mode	1.06	5.03	586	5.08	0.79	0.414	24.5
BLW02	In Bypass Mode	1.05	4.61	600	5.05	0.64	0.423	23.2
	Average	1.1	4.8	595	5.1	0.71	0.42	23.9
BLWT1	Two Corning Traps	1.16	6.31	676	4.85	0.18	0.477	18.8
BLDT1	Dummy Trap	1.06	5.41	596	4.83	0.73	0.421	22.9
RBL1	Baseline Check	1.03	3.75	581	5.45	0.51	0.409	25.2
JMBL1	JM Trap	0.42	4.07	607	5.53	0.28	0.426	24.9

Some maximum power data along with associated exhaust pressures are given in Table 10. These data illustrate that at lower engine speeds the installation of two Corning particulate traps between the exhaust manifold and the turbocharger had a relatively large effect on the maximum power attainable even at essentially steady-state operating conditions. Also, the pressure drop across two Corning particulate traps in parallel is relatively low in comparison with the total backpressure at the exhaust manifold.

TABLE 10. MAXIMUM POWER AND EXHAUST PRESSURES WITH AND WITHOUT PARTICULATE TRAP

Engine Speed, rpm	Maximum Torque ft-lb w/o Trap	With Trap[a]	Pressure Trap ΔP, "H_2O("Hg)	Ex. Man., "Hg
1100	1220	550[b]	6 (0.4)	3
1300	1270	750[b]	8(0.6)	6
1500	1235	ND[c]	ND[c]	ND[c]
1700	1165	1050	20(1.5)	25
1900	1095	1085	25(1.8)	34
2100	1010	995	28(2.1)	40

[a]Two Corning particulate traps and bypass system
[b]Considerable time required to attain these conditions
[c]Manifold temperature exceeded 800°C

Again, discussion of engine performance has been based solely on observations, since system optimization for best engine performance was not included in this work assignment. It does appear, however, that system optimization for best engine performance is an important criterion that should be considered in decisions regarding the use of particulate traps in a pre-turbocharger location.

E. Regeneration of Corning Particulate Traps

With the two Corning particulate traps, there was never any indication of any regeneration having occurred during operation over the transient cycle with either clean traps or with the traps loaded to two times initial differential pressures. Regeneration in this configuration was conducted at a steady-state engine speed of 1800 rpm with a torque setting producing a particulate trap inlet temperature of 650°C. This condition was held until the trap outlet temperature reached 640°C. The differential pressure across the traps returned to the initial clean differential pressure.

With the one clean Corning particulate trap installed between the exhaust manifold and the turbocharger, differential pressure across the trap at an engine speed of 2100 rpm with maximum power was 95 inches of water (with two traps at essentially the same operating condition the differential pressure was about 40 inches of water). After loading the trap to a differential pressure of about 1.5 times the differential pressure with a clean trap, the differential pressure was three to six percent lower following each of several transient cycle tests. This series of evaluations is summarized as follows:

Operation and/or Condition	Temperature, °C		Trap DPa, "H_2O
	Exhaust Man.	Trap Out	
Clean Trap - 1800 rpm, 500 Torque	490	480	54
Map and Prep	--	--	--
Three Each Transient Cycles	780	570	--
1800 rpm, 500 Torque	490	480	61
1800 rpm, 500 Torque for 2.5 Hours	490	480	75
Transient Cycle	780	570	--
1800 rpm, 500 Torque	490	480	73
Transient Cycle	780	570	--
1800 rpm, 500 Torque	490	480	70
1800 rpm, 500 Torque for 1 Hour	490	480	80
Transient Cycle	780	570	--
1800 rpm, 500 Torque	490	480	75
1800 rpm, Torque to get 640°C	640	640	--
1800 rpm, 500 Torque	490	480	56

[a]Differential pressure

These results indicate that some limited amount of regeneration was occurring during operation over the transient cycle. The portions of the transient cycle producing the higher exhaust temperatures are shown in Figure 7. As shown from the data on the figure, the time at elevated temperatures is relatively short.

In summary, some limited amount of regeneration occurred during operation over the transient cycle with one Corning particulate trap close-connected to the exhaust manifold. By design optimization of the system, along with some modification in engine operation to obtain slightly higher temperatures, effective regeneration during the transient cycle should be attainable.

F. Regeneration of the Johnson Matthey Particulate Trap

The Johnson Matthey Number CTO-JM 13/VI particulate trap designed for heavy-duty applications was installed into the exhaust system downstream of the turbocharger. The sequence of operation with this trap was as shown on the following page.

As indicated from these data, no regeneration occurred during operation over the transient cycle. In steady-state operation, regeneration was not initiated below a trap inlet temperature of 630°C along with a trap outlet temperature of 520°C.

Sulfate analyses were conducted using the samples collected on the ninety millimeter Pallflex particulate filters (see note below tabulation). Results of these sulfate analyses aree summarized as follows:

Test	Cycle	Configuration	Part.	Sul.[a]
RBLC1	Cold	Baseline	13	1.0
RBLH1	Hot	Baseline	10	0.9
JMBLC	Cold	JM 13/VI Trap	7	0.4
JMBLH	Hot	JM 13/VI Trap	5	0.3

[a]Pallflex, rather than Fluoropore, filters were used for these analyses.

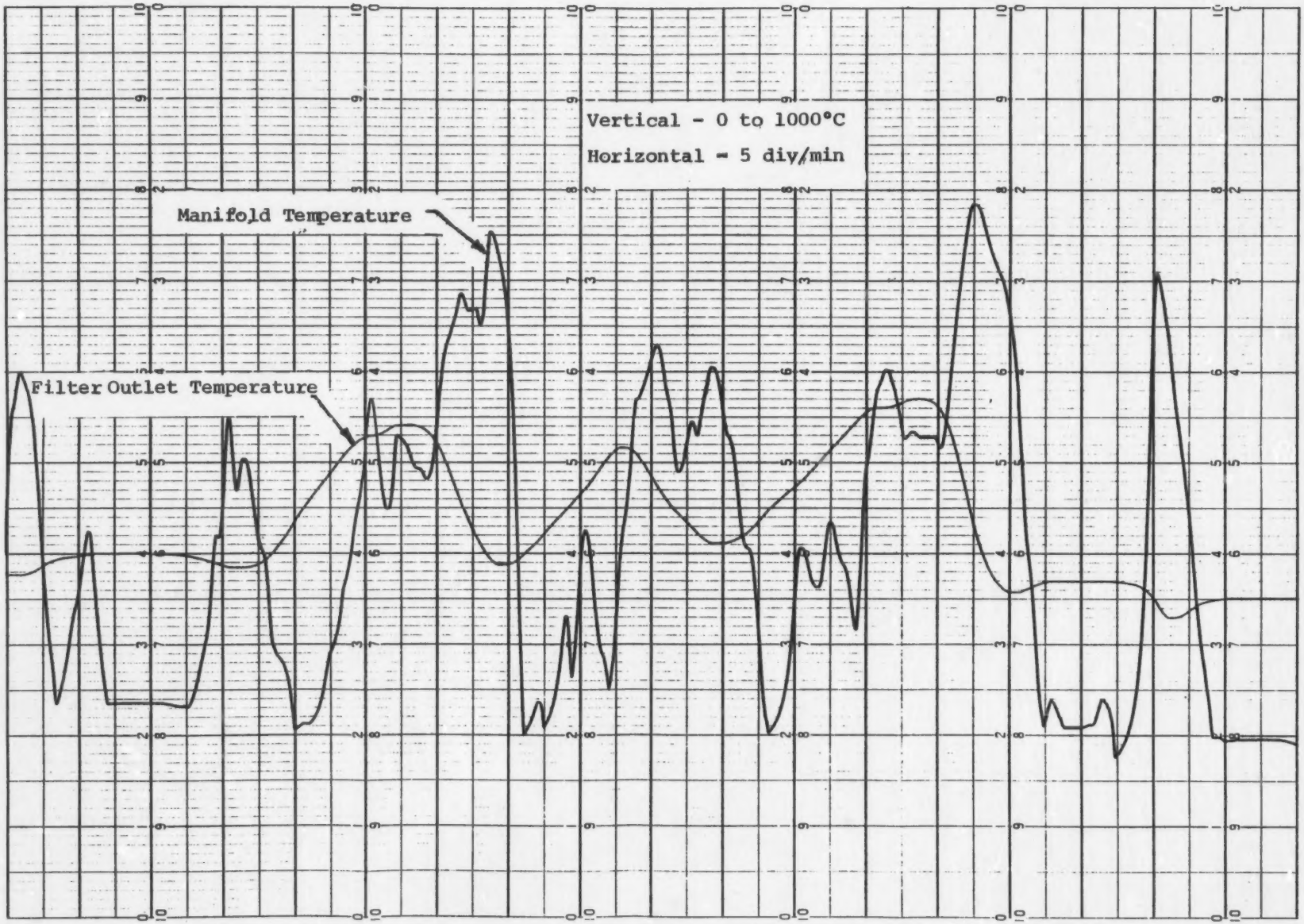


Figure 7. Maximum exhaust temperature during transient cycle with one Corning particulate trap

Based on these data, sulfate emissions were lower with the Johnson Matthey trap installed, than with the baseline exhaust configuration.

Operation and/or Condition	Trap ΔP, "H_2O	Exhaust Temp., °C Man.	Trap Inlet	Trap Outlet
1800 rpm, 500 Torque	20	490	420	370
2100 rpm, 1015 Torque	57	625	505	480
1800 rpm, 500 Torque	22	490	425	400
Power Map and Prep	--	730	640	470
Two Transient Cycles	--	610	470	360
1800 rpm, 500 Torque	25	475	400	300
Transient Cycle	--	610	470	370
1800 rpm, 500 Torque	27	485	410	330
1800 rpm, 500 Torque for 1.2 hours	40	500	440	390
Two Transient Cycles	--	630	490	375
1800 rpm, 500 Torque	44	480	410	300
1800 rpm, 1000 Torque	--	650	545	480
1800 rpm, 500 Torque	45	510	480	435
1300 rpm, 1100 Torque	GD[a]	730	650	550
1300 rpm, 1200 Torque	RD[b]	750	670	595
1800 rpm, 500 Torque	25	490	440	460
1800 rpm, 500 Torque for 1.8 hours	42	510	440	390
Transient Cycle	--	630	495	370
1800 rpm, 500 Torque	40	485	425	355
1300 rpm, 1000 Torque	GD[a]	700	630	520
1300 rpm, 1200 Torque	RD[b]	740	660	580
1800 rpm, 500 Torque	22	460	405	360

[a]Gradual decrease began
[b]Rapid decrease

REFERENCES

1. Federal Register, "Gaseous Emission Regulations for 1984 and Later Model Year Heavy-Duty Engines," Part II, Vol. 45, No. 14, January 21, 1980.

2. Federal Register, "Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines; Particulate Regulation for Heavy-Duty Diesel Engines," Proposed Rules Part III, Vol. 46, No. 4, January 7, 1981.

3. France, C.J., et al, "Recommended Practice for Determining Exhaust Emissions from Heavy-Duty Vehicles under Transient Conditions," Technical Report SDSB 79-80, Environmental Protection Agency, Ann Arbor, MI. The cycle was subsequently included in the Federal Register, "Evaporative Emission Regulation and Test Procedure for 1985 and Later Model Year Gasoline-Fueled Heavy-Duty Vehicles; Final Rule" Part IV, Vol. 48, No. 8, January 12, 1983.

4. Howitt, J.S. and Montierth, M.R., "Cellular Ceramic Diesel Particulate Filter," SAE Paper 810114 presented at the International Congress and Exposition, Cobo Hall, Detroit, Michigan, February 23-27, 1981.

5. Wade, W.R., White, J.E., and Florek, J.J., "Diesel Particulate Trap Regeneration Techniques," SAE Paper 810118 presented at the International Congress and Exposition, Cobo Hall, Detroit, Michigan, February 23-27, 1981.

6. Urban, C.M., Landman, L.C., and Wagner, R.D., "Diesel Car Particulate Control Methods," SAE Paper 830083 presented at the International Congress and Exposition, Detroit, Michigan, February 28-March 4, 1983.

APPENDICES

A. ENGINE BASELINE EVALUATIONS

B. PARTICULATE TRAP BYPASS SYSTEM

C. EXHAUST PARTICULATE TRAP RESULTS

APPENDIX A

ENGINE BASELINE EVALUATIONS

A-2 through A-5	Computer Printouts of Transient Evaluations
A-6 through A-10	Summaries of Steady-State Evaluations
A-11 through A-15	Computer Printouts of Steady-State Evaluations

TABLE ENGINE EMISSION RESULTS
C-TRANS.

PROJECT NO. 05-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST BL-1 RUN1
DATE 12/ 2/83
TIME
DYNO NO. 5

BASELINE ENGINE
DIESEL EM-528-F
BAG CART NO. 1

BAROMETER 739.65 MM HG(29.12 IN HG)
DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)

RELATIVE HUMIDITY , ENGINE-56. PCT , CVS-60. PCT
ABSOLUTE HUMIDITY 11.4 GM/KG(80.1 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1199.0
TOTAL FLOW STD. CU. METRES(SCF)	***** (38208.)
HC SAMPLE METER/RANGE/PPM	50.3/22/ 50.
HC BCKGRD METER/RANGE/PPM	9.5/ 2/ 10.
CO SAMPLE METER/RANGE/PPM	73.8/13/ 72.
CO BCKGRD METER/RANGE/PPM	2.2/13/ 2.
CO2 SAMPLE METER/RANGE/PCT	88.7/11/ .87
CO2 BCKGRD METER/RANGE/PCT	8.7/11/ .05
NOX SAMPLE METER/RANGE/PPM	70.9/ 2/ 71.
NOX BCKGRD METER/RANGE/PPM	.7/ 2/ 1.
DILUTION FACTOR	15.22
HC CONCENTRATION PPM	41.
CO CONCENTRATION PPM	68.
CO2 CONCENTRATION PCT	.82
NOX CONCENTRATION PPM	70.2
HC MASS GRAMS	25.86
CO MASS GRAMS	85.49
CO2 MASS GRAMS	16226.8
NOX MASS GRAMS	145.36
FUEL KG (LB)	5.166 (11.39)
KW HR (HP HR)	18.78 (25.19)
BSHC G/KW HR (G/HP HR)	1.38 (1.03)
BSCO G/KW HR (G/HP HR)	4.55 (3.39)
BSCO2 G/KW HR (G/HP HR)	863.85 (644.18)
BSNOX G/KW HR (G/HP HR)	7.74 (5.77)
BSFC KG/KW HR (LB/HP HR)	.275 (.452)

TOTAL TEST RESULTS 1 BAGS

TOTAL KW HR (HP HR)	18.78 (25.19)
BSHC G/KW HR (G/HP HR)	1.38 (1.03)
BSCO G/KW HR (G/HP HR)	4.55 (3.39)
BSCO2 G/KW HR (G/HP HR)	864. (644.)
BSNOX G/KW HR (G/HP HR)	7.74 (5.77)
BSFC KG/KW HR (LB/HP HR)	.275 (.452)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	15.01
	G/KWHR(G/HPHR)	.80 (.60)
	G/KG FUEL (G/LB FUEL)	2.91 (1.32)
	FILTER EFF.	96.1

TABLE ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 05-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST BL-0 RUN1
DATE 12/ 1/83
TIME
DYNO NO. 5

BASELINE ENGINE
DIESEL EM-528-F
BAG CART NO. 1

BAROMETER 745.49 MM HG(29.35 IN HG)
DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)

RELATIVE HUMIDITY , ENGINE-45. PCT , CVS-66. PCT
ABSOLUTE HUMIDITY 9.4 GM/KG(65.8 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS	
BAG NUMBER	1
TIME SECONDS	1199.0
TOTAL FLOW STD. CU. METRES(SCF)	***** (38623.)
HC SAMPLE METER/RANGE/PPM	24.3/22/ 24.
HC BCKGRD METER/RANGE/PPM	9.0/ 2/ 9.
CO SAMPLE METER/RANGE/PPM	61.8/13/ 59.
CO BCKGRD METER/RANGE/PPM	.8/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	87.8/11/ .85
CO2 BCKGRD METER/RANGE/PCT	11.0/11/ .07
NOX SAMPLE METER/RANGE/PPM	79.9/ 2/ 80.
NOX BCKGRD METER/RANGE/PPM	.8/ 2/ 1.
DILUTION FACTOR	15.53
HC CONCENTRATION PPM	16.
CO CONCENTRATION PPM	56.
CO2 CONCENTRATION PCT	.79
NOX CONCENTRATION PPM	79.2
HC MASS GRAMS	10.00
CO MASS GRAMS	71.91
CO2 MASS GRAMS	15848.2
NOX MASS GRAMS	165.57
FUEL KG (LB)	5.024 (11.08)
KW HR (HP HR)	19.87 (26.65)
BSHC G/KW HR (G/HP HR)	.50 (.38)
BSCO G/KW HR (G/HP HR)	3.62 (2.70)
BSCO2 G/KW HR (G/HP HR)	797.48 (594.68)
BSNOX G/KW HR (G/HP HR)	8.33 (6.21)
BSFC KG/KW HR (LB/HP HR)	.253 (.416)

TOTAL TEST RESULTS 1 BAGS

TOTAL KW HR (HP HR)	19.87 (	26.65)
BSHC G/KW HR (G/HP HR)	.50 (	.38)
BSCO G/KW HR (G/HP HR)	3.62 (	2.70)
BSCO2 G/KW HR (G/HP HR)	797. (	595.)
BSNOX G/KW HR (G/HP HR)	8.33 (	6.21)
BSFC KG/KW HR (LB/HP HR)	.253 (	.416)

EXHAUST TEMPERATURE AND OXYGEN MAP AT STANDARD CONDITIONS
Cummins NTC-400 (CPL531)
Intake Restriction Set at 20"H_2O at 2100 rpm

Speed, rpm	Torque, ft-lbs	Fuel, lb/hr	BSFC, lb/hp-hr	Exhaust Temp., °C			Exhaust Oxygen, % by Vol
				Pre-Turbo[a]	Post-Turbo	Two Feet from Turbo[b]	
700	380	20	0.39	380	--	330	11.4
700	510	27	0.40	460	--	390	8.8
700	580	33	0.42	520	--	440	7.5
700	655	38	0.44	570	--	485	6.0
900	460	28	0.36	450	--	400	9.6
900	620	40	0.37	520	--	445	8.4
900	700	45	0.38	570	--	485	7.3
900	1080	88	0.47	760	--	730	2.7
1100	595	44	0.35	560	515	500	8.2
1100	800	60	0.36	645	585	560	6.0
1100	905	74	0.39	695	625	600	5.0
1100	1245	98	0.38	810	--	710	2.4
1300	750	67	0.36	570	--	510	8.3
1300	1000	90	0.36	650	--	575	5.9
1300	1125	101	0.36	700	625	610	4.8
1300	1280	113	0.36	730	--	640	4.0
1500	730	73	0.35	535	--	480	10.3
1500	965	93	0.34	585	--	510	8.5
1500	1090	106	0.34	605	545	535	8.0
1500	1230	122	0.35	640	--	545	7.5
1700	700	78	0.35	510	--	445	11.5
1700	925	104	0.35	550	--	465	10.1
1700	1040	114	0.34	565	485	475	9.8
1700	1165	125	0.33	590	--	490	9.3
1900	660	88	0.37	480	--	400	12.5
1900	880	112	0.35	520	--	425	11.5
1900	990	125	0.35	545	450	445	11.0
1900	1090	137	0.35	575	--	455	10.5
2100	600	90	0.37	465	--	385	13.3
2100	800	116	0.36	510	--	410	12.3
2100	900	130	0.36	530	425	420	11.9
2100	995	143	0.36	550	--	435	11.4

[a] Average of front and rear exhaust bank; temperature difference was less than 10°C (18°F). Insulating an exhaust bank increased temperatures by less than 10°C (18°F) at nominal speeds and torques.

[b] With exhaust pipe uninsulated

TABLE ENGINE EMISSION RESULTS
C-TRANS.

PROJECT NO. 05-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST BL-2 RUN1
DATE 12/ 7/83
TIME
DYNO NO. 5

BASELINE ENGINE
DIESEL EM-528-F
BAG CART NO. 1

BAROMETER 751.08 MM HG(29.57 IN HG)
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)

RELATIVE HUMIDITY , ENGINE-51. PCT , CVS-24. PCT
ABSOLUTE HUMIDITY 9.5 GM/KG(66.3 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS	
BAG NUMBER	1
TIME SECONDS	1199.0
TOTAL FLOW STD. CU. METRES(SCF)	***** (39083.)
HC SAMPLE METER/RANGE/PPM	47.7/22/ 48.
HC BCKGRD METER/RANGE/PPM	7.4/ 2/ 7.
CO SAMPLE METER/RANGE/PPM	82.7/13/ 82.
CO BCKGRD METER/RANGE/PPM	5.6/13/ 5.
CO2 SAMPLE METER/RANGE/PCT	89.3/11/ .88
CO2 BCKGRD METER/RANGE/PCT	8.2/11/ .05
NOX SAMPLE METER/RANGE/PPM	80.1/ 2/ 80.
NOX BCKGRD METER/RANGE/PPM	.6/ 2/ 1.
DILUTION FACTOR	15.05
HC CONCENTRATION PPM	41.
CO CONCENTRATION PPM	75.
CO2 CONCENTRATION PCT	.83
NOX CONCENTRATION PPM	79.5
HC MASS GRAMS	26.05
CO MASS GRAMS	97.29
CO2 MASS GRAMS	16846.0
NOX MASS GRAMS	168.37
FUEL KG (LB)	5.366 (11.83)
KW HR (HP HR)	19.08 (25.59)
BSHC G/KW HR (G/HP HR)	1.37 (1.02)
BSCO G/KW HR (G/HP HR)	5.10 (3.80)
BSCO2 G/KW HR (G/HP HR)	882.80 (658.31)
BSNOX G/KW HR (G/HP HR)	8.82 (6.58)
BSFC KG/KW HR (LB/HP HR)	.281 (.462)

TOTAL TEST RESULTS 1 BAGS

TOTAL KW HR (HP HR)	19.08 (25.59)
BSHC G/KW HR (G/HP HR)	1.37 (1.02)
BSCO G/KW HR (G/HP HR)	5.10 (3.80)
BSCO2 G/KW HR (G/HP HR)	883. (658.)
BSNOX G/KW HR (G/HP HR)	8.82 (6.58)
BSFC KG/KW HR (LB/HP HR)	.281 (.462)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	13.70
	G/KWHR(G/HPHR)	.72 (.54)
	G/KG FUEL (G/LB FUEL)	2.55 (1.16)
	FILTER EFF.	95.8

TABLE ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 05-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST INS-0 RUN1
DATE 12/ 1/83
TIME
DYNO NO. 5

INSULATED MANIFOLD
DIESEL EM-528-F
BAG CART NO. 1

BAROMETER 744.98 MM HG(29.33 IN HG)
DRY BULB TEMP. 22.8 DEG C(73.0 DEG F)

RELATIVE HUMIDITY , ENGINE-49. PCT , CVS-44. PCT
ABSOLUTE HUMIDITY 8.7 GM/KG(60.6 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS	
BAG NUMBER	1
TIME SECONDS	1199.0
TOTAL FLOW STD. CU. METRES(SCF)	***** (38636.)
HC SAMPLE METER/RANGE/PPM	24.1/22/ 24.
HC BCKGRD METER/RANGE/PPM	6.0/ 2/ 6.
CO SAMPLE METER/RANGE/PPM	62.1/13/ 60.
CO BCKGRD METER/RANGE/PPM	.8/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	86.7/11/ .84
CO2 BCKGRD METER/RANGE/PCT	9.2/11/ .06
NOX SAMPLE METER/RANGE/PPM	81.7/ 2/ 82.
NOX BCKGRD METER/RANGE/PPM	.6/ 2/ 1.
DILUTION FACTOR	15.83
HC CONCENTRATION PPM	19.
CO CONCENTRATION PPM	57.
CO2 CONCENTRATION PCT	.79
NOX CONCENTRATION PPM	81.1
HC MASS GRAMS	11.68
CO MASS GRAMS	72.87
CO2 MASS GRAMS	15741.2
NOX MASS GRAMS	169.78
FUEL KG (LB)	4.993 (11.01)
KW HR (HP HR)	19.76 (26.50)
BSHC G/KW HR (G/HP HR)	.59 (.44)
BSCO G/KW HR (G/HP HR)	3.69 (2.75)
BSCO2 G/KW HR (G/HP HR)	796.58 (594.01)
BSNOX G/KW HR (G/HP HR)	8.59 (6.41)
BSFC KG/KW HR (LB/HP HR)	.253 (.415)

TOTAL TEST RESULTS 1 BAGS

TOTAL KW HR (HP HR)	19.76 (26.50)
BSHC G/KW HR (G/HP HR)	.59 (.44)
BSCO G/KW HR (G/HP HR)	3.69 (2.75)
BSCO2 G/KW HR (G/HP HR)	797. (594.)
BSNOX G/KW HR (G/HP HR)	8.59 (6.41)
BSFC KG/KW HR (LB/HP HR)	.253 (.415)

EXHAUST TEMPERATURE AND OXYGEN MAP AT STANDARD CONDITIONS
Cummins NTC-400 (CPL531)
Intake Restriction Set at 20"H_2O at 2100 rpm

Speed, rpm	Torque, ft-lbs	Fuel, lb/hr	BSFC, lb/hp-hr	Exhaust Temp., °C			Exhaust Oxygen, % by Vol
				Pre-Turbo[a]	Post-Turbo	Two Feet from Turbo[b]	
700	380	20	0.39	380	--	330	11.4
700	510	27	0.40	460	--	390	8.8
700	580	33	0.42	520	--	440	7.5
700	655	38	0.44	570	--	485	6.0
900	460	28	0.36	450	--	400	9.6
900	620	40	0.37	520	--	445	8.4
900	700	45	0.38	570	--	485	7.3
900	1080	88	0.47	760	--	730	2.7
1100	595	44	0.35	560	515	500	8.2
1100	800	60	0.36	645	585	560	6.0
1100	905	74	0.39	695	625	600	5.0
1100	1245	98	0.38	810	--	710	2.4
1300	750	67	0.36	570	--	510	8.3
1300	1000	90	0.36	650	--	575	5.9
1300	1125	101	0.36	700	625	610	4.8
1300	1280	113	0.36	730	--	640	4.0
1500	730	73	0.35	535	--	480	10.3
1500	965	93	0.34	585	--	510	8.5
1500	1090	106	0.34	605	545	535	8.0
1500	1230	122	0.35	640	--	545	7.5
1700	700	78	0.35	510	--	445	11.5
1700	925	104	0.35	550	--	465	10.1
1700	1040	114	0.34	565	485	475	9.8
1700	1165	125	0.33	590	--	490	9.3
1900	660	88	0.37	480	--	400	12.5
1900	880	112	0.35	520	--	425	11.5
1900	990	125	0.35	545	450	445	11.0
1900	1090	137	0.35	575	--	455	10.5
2100	600	90	0.37	465	--	385	13.3
2100	800	116	0.36	510	--	410	12.3
2100	900	130	0.36	530	425	420	11.9
2100	995	143	0.36	550	--	435	11.4

[a] Average of front and rear exhaust bank; temperature difference was less than 10°C (18°F). Insulating an exhaust bank increased temperatures by less than 10°C (18°F) at nominal speeds and torques.

[b] With exhaust pipe uninsulated

EXHAUST TEMPERATURE AND OXYGEN MAP AT STANDARD CONDITIONS
Cummins NTC-400 (CPL531)
Intake Restriction Set at 20"H_2O at 2100 rpm

Speed, rpm	Torque, ft-lbs	Fuel, lb/hr	BSFC, lb/hp-hr	Exhaust Temp., °F		
				Pre-Turbo[a]	Post-Turbo	Two Feet from Turbo[b]
700	380	20	0.39	716	--	626
700	510	27	0.40	860	--	734
700	580	33	0.42	968	--	824
700	655	38	0.44	1058	--	905
900	460	28	0.36	842	--	752
900	620	40	0.37	968	--	833
900	700	45	0.38	1058	--	905
900	1080	88	0.47	1400	--	1346
1100	595	44	0.35	1040	959	932
1100	800	60	0.36	1193	1085	1040
1100	905	74	0.39	1283	1157	1112
1100	1245	98	0.38	1490	--	1310
1300	750	67	0.36	1058	--	950
1300	1000	90	0.36	1202	--	1067
1300	1125	101	0.36	1292	1157	1130
1300	1280	113	0.36	1346	--	1184
1500	730	73	0.35	995	--	896
1500	965	93	0.34	1085	--	950
1500	1090	106	0.34	1121	1013	995
1500	1230	122	0.35	1184	--	1013
1700	700	78	0.35	950	--	833
1700	925	104	0.35	1022	--	869
1700	1040	114	0.34	1049	905	887
1700	1165	125	0.33	1094	--	914
1900	660	88	0.37	896	--	752
1900	880	112	0.35	968	--	797
1900	990	125	0.35	1013	842	833
1900	1090	137	0.35	1067	--	851
2100	600	90	0.37	869	--	725
2100	800	116	0.36	950	--	770
2100	900	130	0.36	986	797	788
2100	995	143	0.36	1022	--	815

[a] Average of front and rear exhaust bank; temperature difference was less than 10°C (18°F). Insulating an exhaust bank increased temperatures by less than 10°C (18°F) at nominal speeds and torques.
[b] With exhaust pipe uninsulated

EXHAUST EMISSION MEASUREMENTS FROM THE MAP AT STANDARD CONDITIONS
Cummins NTC-400 (CPL531)
Intake Restriction Set at 20"H_2O at 2100 rpm

Speed, rpm	Torque, ft-lbs	Fuel, lb/hr	BSFC, lb/hp-hr	Undiluted Exhaust Emissions HC, ppmC	CO, ppm	CO_2, %	NO_x, ppm
700	380	20	0.39	--	--	--	--
700	510	27	0.40	--	--	--	--
700	580	33	0.42	--	--	--	--
700	655	38	0.44	--	--	--	--
900	460	28	0.36	--	--	--	--
900	620	40	0.37	--	--	--	--
900	700	45	0.38	--	--	--	--
900	1080	88	0.47	--	--	--	--
1100	595	44	0.35	--	--	--	--
1100	800	60	0.36	--	--	--	--
1100	905	74	0.39	--	--	--	--
1100	1245	98	0.38	--	--	--	--
1300	750	67	0.36	62	665	8.89	1275
1300	1000	90	0.36	48	1675	10.42	1665
1300	1125	101	0.36	43	2664	10.90	1800
1300	1280	113	0.36	44	3578	11.14	1935
1500	730	73	0.35	64	286	7.44	1170
1500	965	93	0.34	66	446	8.58	1605
1500	1090	106	0.34	70	582	8.99	1830
1500	1230	122	0.35	83	776	9.31	2055
1700	700	78	0.35	54	88	6.57	990
1700	925	104	0.35	65	212	7.71	1440
1700	1040	114	0.34	67	226	7.81	1650
1700	1165	125	0.33	75	266	8.09	1905
1900	660	88	0.37	60	119	6.16	2535
1900	880	112	0.35	60	119	6.91	1230
1900	990	125	0.35	59	119	7.17	1485
1900	1090	137	0.35	63	146	7.44	1710
2100	600	90	0.37	59	106	5.53	2190
2100	800	116	0.36	59	106	6.32	1065
2100	900	130	0.36	59	119	6.57	1260
2100	995	143	0.36	62	106	6.82	1470

[a] Average of front and rear exhaust bank; temperature difference was less than 10°C (18°F). Insulating an exhaust bank increased temperatures by
[b] less than 10°C (18°F) at nominal speeds and torques.
With exhaust pipe uninsulated

MODAL GASEOUS AND PARTICULATE EMISSIONS DATA

Speed, rpm	Torque, ft-lb	Measured Fuel, lb/hr	Measured BSFC, lb/hp-hr	Emissions, g/hp-hr HC	CO	CO_2	NO_x	Part.	C.B. BSFC, lb/hp-hr
900	1130	85.5	0.442	0.12	7.7	629	6.3	1.27	0.444
1300	1278	115.0	0.364	0.07[a]	7.7[a]	503[a]	9.6[a]	0.22[a]	0.357[a]
1700	1164	127.0	0.337	0.15	0.8	470	10.6	0.10	0.326
1900	1086	134.6	0.343	0.14	0.5	475	10.2	0.14	0.330
2100	1000	139.6	0.349	0.15	0.4	497	10.2	0.13	0.345

Speed, rpm	Torque, N•m	Measured Fuel, kg/hr	Measured BSFC, kg/kW-hr	Emissions, g/kW-hr HC	CO	CO_2	NO_x	Part.	C.B. SFC, kg/kW-hr
900	1532	38.8	269	0.15	10.4	843	8.5	1.70	0.270
1300	1733	52.2	221	0.10[a]	10.4[a]	674[a]	12.9[a]	0.29[a]	0.217[a]
1700	1578	57.6	205	0.20	1.1	630	14.2	0.13	0.199
1900	1475	61.1	208	0.18	0.7	636	13.7	0.18	0.200
2100	1356	63.3	212	0.21	0.5	666	13.7	0.18	0.210

[a]Data adjusted based on average difference between measured and carbon balance (C.B.) BSFC for the other four engine speeds.

EXHAUST TEMPERATURE AND OXYGEN WITH INTAKE RESTRICTION
Cummins NTC-400 (CPL531)
Intake Restriction Set at Maximum - 73"H_2O at 2100 rpm

Speed, rpm	Torque, ft-lbs	Fuel, lb/hr	Exhaust Temp., °C		Oxygen, % by Vol	Exhaust Temp., °C Max.-Std. Restriction	
			Pre-Turbo[a]	Two Feet from Turbo[b]		Pre-Turbo[a]	Two Feet from Turbo[b]
700	380	19	410	370	10.7	30	40
700	510	28	485	420	8.3	25	30
700	580	32	530	450	7.3	10	10
700	650	37	580	495	5.8	10	10
900	460	28	460	410	9.4	10	10
900	620	40	530	455	8.2	10	10
900	700	46	570	490	7.3	0	5
900	1020	88	750	655	2.9	-10	25
1100	600	44	570	505	8.0	10	5
1100	805	63	665	570	5.8	20	10
1100	905	72	710	615	4.8	15	15
1100	1226	98	820	730	2.2	10	20
1300	745	66	630	550	6.5	60	40
1300	1000	89	720	615	4.3	70	40
1300	1135	101	775	665	3.0	75	55
1300	1260	112	820	695	2.4	90	55
1500	730	73	565	510	9.8	30	30
1500	980	93	635	570	7.8	50	40
1500	1095	105	660	580	7.0	55	55
1500	1230	120	685	590	6.5	45	45
1700	700	79	570	490	10.1	60	45
1700	925	102	620	510	8.6	70	45
1700	1040	117	640	530	7.7	75	55
1700	1165	127	680	545	7.1	90	55
1900	660	86	540	465	11.5	60	65
1900	880	111	590	490	10.0	70	65
1900	990	124	610	505	9.5	65	60
1900	1095	137	640	530	9.0	65	75
2100	600	93	520	445	12.3	55	60
2100	800	115	585	485	10.8	75	75
2100	900	125	615	505	10.0	85	85
2100	1005	143	645	525	9.4	95	90

[a] Average of temperatures for front and rear exhaust banks
[b] Exhaust pipe without insulation

TABLE ENGINE EMISSION RESULTS
900 RPM

PROJECT NO. 05-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST 900-1 RUN1
DATE 12/19/83
TIME
DYNO NO. 5

DIESEL EM-528-F
BAG CART NO. 1

BAROMETER 748.54 MM HG(29.47 IN HG)
DRY BULB TEMP. 22.8 DEG C(73.0 DEG F)

RELATIVE HUMIDITY , ENGINE-51. PCT , CVS-18. PCT
ABSOLUTE HUMIDITY 8.9 GM/KG(62.2 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	359.6
TOTAL FLOW STD. CU. METRES(SCF)	821.6 (29019.)
HC SAMPLE METER/RANGE/PPM	12.0/ 2/ 12.
HC BCKGRD METER/RANGE/PPM	8.0/ 2/ 8.
CO SAMPLE METER/RANGE/PPM	68.5/12/ 155.
CO BCKGRD METER/RANGE/PPM	1.4/12/ 3.
CO2 SAMPLE METER/RANGE/PCT	85.1/11/ .81
CO2 BCKGRD METER/RANGE/PCT	7.8/11/ .05
NOX SAMPLE METER/RANGE/PPM	74.7/ 2/ 75.
NOX BCKGRD METER/RANGE/PPM	.6/ 2/ 1.
DILUTION FACTOR	16.13
HC CONCENTRATION PPM	4.
CO CONCENTRATION PPM	149.
CO2 CONCENTRATION PCT	.77
NOX CONCENTRATION PPM	74.1
HC MASS GRAMS	2.13
CO MASS GRAMS	142.72
CO2 MASS GRAMS	11593.3
NOX MASS GRAMS	116.52
FUEL KG (LB)	3.715 (8.19)
KW HR (HP HR)	13.75 (18.44)
BSHC G/KW HR (G/HP HR)	.15 (.12)
BSCO G/KW HR (G/HP HR)	10.38 (7.74)
BSCO2 G/KW HR (G/HP HR)	843.11 (628.71)
BSNOX G/KW HR (G/HP HR)	8.47 (6.32)
BSFC KG/KW HR (LB/HP HR)	.270 (.444)

TOTAL TEST RESULTS 1 BAGS

TOTAL KW HR (HP HR)	13.75 (18.44)
BSHC G/KW HR (G/HP HR)	.15 (.12)
BSCO G/KW HR (G/HP HR)	10.38 (7.74)
BSCO2 G/KW HR (G/HP HR)	843. (629.)
BSNOX G/KW HR (G/HP HR)	8.47 (6.32)
BSFC KG/KW HR (LB/HP HR)	.270 (.444)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	23.41
	G/KWHR(G/HPHR)	1.70 (1.27)
	G/KG FUEL (G/LB FUEL)	6.30 (2.86)
	FILTER EFF.	97.4

TABLE ENGINE EMISSION RESULTS
1300 RPM

PROJECT NO. 05-7338-003

ENGINE NO.
ENGINE MODEL 0 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST 1300-1 RUN1
DATE 12/19/83
TIME
DYNO NO. 5

DIESEL EM-528-F
BAG CART NO. 1

BAROMETER 746.51 MM HG(29.39 IN HG)
DRY BULB TEMP. 20.0 DEG C(68.0 DEG F)

RELATIVE HUMIDITY , ENGINE-59. PCT , CVS-21. PCT
ABSOLUTE HUMIDITY 8.8 GM/KG(61.4 GRAINS/LB)

NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	499.9
TOTAL FLOW STD. CU. METRES(SCF)	***** (40214.)
HC SAMPLE METER/RANGE/PPM	11.5/ 2/ 12.
HC BCKGRD METER/RANGE/PPM	8.0/ 2/ 8.
CO SAMPLE METER/RANGE/PPM	88.1/12/ 215.
CO BCKGRD METER/RANGE/PPM	.3/12/ 1.
CO2 SAMPLE METER/RANGE/PCT	91.4/11/ .91
CO2 BCKGRD METER/RANGE/PCT	7.5/11/ .04
NOX SAMPLE METER/RANGE/PPM	53.0/ 3/ 159.
NOX BCKGRD METER/RANGE/PPM	.1/ 3/ 0.
DILUTION FACTOR	14.37
HC CONCENTRATION PPM	4.
CO CONCENTRATION PPM	209.
CO2 CONCENTRATION PCT	.87
NOX CONCENTRATION PPM	158.7
HC MASS GRAMS	2.66
CO MASS GRAMS	277.42
CO2 MASS GRAMS	18106.2
NOX MASS GRAMS	345.70
FUEL KG (LB)	5.828 (12.85)
KW HR (HP HR)	32.71 (43.87)
BSHC G/KW HR (G/HP HR)	.08 (.06)
BSCO G/KW HR (G/HP HR)	8.48 (6.32)
BSCO2 G/KW HR (G/HP HR)	553.47 (412.73)
BSNOX G/KW HR (G/HP HR)	10.57 (7.88)
BSFC KG/KW HR (LB/HP HR)	.178 (.293)

TOTAL TEST RESULTS 1 BAGS

TOTAL KW HR (HP HR)	32.71 (43.87)
BSHC G/KW HR (G/HP HR)	.08 (.06)
BSCO G/KW HR (G/HP HR)	8.48 (6.32)
BSCO2 G/KW HR (G/HP HR)	553. (413.)
BSNOX G/KW HR (G/HP HR)	10.57 (7.88)
BSFC KG/KW HR (LB/HP HR)	.178 (.293)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	7.75
	G/KWHR(G/HPHR)	.24 (.18)
	G/KG FUEL (G/LB FUEL)	1.33 (.60)
	FILTER EFF.	94.4

TABLE ENGINE EMISSION RESULTS
1700 RPM

PROJECT NO. 05-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST 1700-1 RUN1
DATE 12/19/83
TIME
DYNO NO. 5

DIESEL EM-528-F
BAG CART NO. 1

BAROMETER 746.25 MM HG(29.38 IN HG)
DRY BULB TEMP. 19.4 DEG C(67.0 DEG F)

RELATIVE HUMIDITY , ENGINE-59. PCT , CVS-19. PCT
ABSOLUTE HUMIDITY 8.5 GM/KG(59.3 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS	
BAG NUMBER	1
TIME SECONDS	605.9
TOTAL FLOW STD. CU. METRES(SCF)	***** (48831.)
HC SAMPLE METER/RANGE/PPM	18.9/ 2/ 19.
HC BCKGRD METER/RANGE/PPM	8.0/ 2/ 8.
CO SAMPLE METER/RANGE/PPM	36.1/13/ 33.
CO BCKGRD METER/RANGE/PPM	.8/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	66.9/ 3/ 1.20
CO2 BCKGRD METER/RANGE/PCT	2.0/ 3/ .03
NOX SAMPLE METER/RANGE/PPM	84.4/ 3/ 253.
NOX BCKGRD METER/RANGE/PPM	.2/ 3/ 1.
DILUTION FACTOR	11.11
HC CONCENTRATION PPM	12.
CO CONCENTRATION PPM	32.
CO2 CONCENTRATION PCT	1.17
NOX CONCENTRATION PPM	252.7
HC MASS GRAMS	9.27
CO MASS GRAMS	51.19
CO2 MASS GRAMS	29712.6
NOX MASS GRAMS	668.19
FUEL KG (LB)	9.369 (20.65)
KW HR (HP HR)	47.19 (63.28)
BSHC G/KW HR (G/HP HR)	.20 (.15)
BSCO G/KW HR (G/HP HR)	1.08 (.81)
BSCO2 G/KW HR (G/HP HR)	629.67 (469.54)
BSNOX G/KW HR (G/HP HR)	14.16 (10.56)
BSFC KG/KW HR (LB/HP HR)	.199 (.326)

TOTAL TEST RESULTS 1 BAGS

TOTAL KW HR (HP HR)	47.19 (63.28)
BSHC G/KW HR (G/HP HR)	.20 (.15)
BSCO G/KW HR (G/HP HR)	1.08 (.81)
BSCO2 G/KW HR (G/HP HR)	630. (470.)
BSNOX G/KW HR (G/HP HR)	14.16 (10.56)
BSFC KG/KW HR (LB/HP HR)	.199 (.326)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	6.07
	G/KWHR(G/HPHR)	.13 (.10)
	G/KG FUEL (G/LB FUEL)	.65 (.29)
	FILTER EFF.	93.4

TA LE ENGINE EMISSION RESULTS
1900 RPM

PROJECT NO. 05-7338-003

ENGINE NO.
ENGINE MODEL 0 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST 1900 RUN1
DATE 12/19/83
TIME
DYNO NO. 5

DIESEL EM-528-F
BAG CART NO. 1

BAROMETER 746.76 MM HG(29.40 IN HG)
DRY BULB TEMP. 20.0 DEG C(68.0 DEG F)

RELATIVE HUMIDITY , ENGINE-61. PCT , CVS-21. PCT
ABSOLUTE HUMIDITY 9.0 GM/KG(63.0 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	600.1
TOTAL FLOW STD. CU. METRES(SCF)	***** (48319.)
HC SAMPLE METER/RANGE/PPM	18.6/ 2/ 19.
HC BCKGRD METER/RANGE/PPM	8.0/ 2/ 8.
CO SAMPLE METER/RANGE/PPM	24.4/13/ 22.
CO BCKGRD METER/RANGE/PPM	.7/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	71.1/ 3/ 1.29
CO2 BCKGRD METER/RANGE/PCT	3.1/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	85.8/ 3/ 257.
NOX BCKGRD METER/RANGE/PPM	.6/ 3/ 2.
DILUTION FACTOR	10.38
HC CONCENTRATION PPM	11.
CO CONCENTRATION PPM	21.
CO2 CONCENTRATION PCT	1.24
NOX CONCENTRATION PPM	255.8
HC MASS GRAMS	8.97
CO MASS GRAMS	33.50
CO2 MASS GRAMS	31159.6
NOX MASS GRAMS	669.35
FUEL KG (LB)	9.814 (21.64)
KW HR (HP HR)	48.96 (65.65)
BSHC G/KW HR (G/HP HR)	.18 (.14)
BSCO G/KW HR (G/HP HR)	.68 (.51)
BSCO2 G/KW HR (G/HP HR)	636.49 (474.63)
BSNOX G/KW HR (G/HP HR)	13.67 (10.20)
BSFC KG/KW HR (LB/HP HR)	.200 (.330)

TOTAL TEST RESULTS 1 BAGS

TOTAL KW HR (HP HR)	48.96 (65.65)
BSHC G/KW HR (G/HP HR)	.18 (.14)
BSCO G/KW HR (G/HP HR)	.68 (.51)
BSCO2 G/KW HR (G/HP HR)	636. (475.)
BSNOX G/KW HR (G/HP HR)	13.67 (10.20)
BSFC KG/KW HR (LB/HP HR)	.200 (.330)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	8.87
	G/KWHR(G/HPHR)	.18 (.14)
	G/KG FUEL (G/LB FUEL)	.90 (.41)
	FILTER EFF.	94.1

TABLE ENGINE EMISSION RESULTS
2100 RPM

PROJECT NO. 05-7338-003

ENGINE NO.
ENGINE MODEL 0 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST 2100 RUN1
DATE 12/19/83
TIME
DYNO NO. 5

DIESEL EM-528-F
BAG CART NO. 1

BAROMETER 746.51 MM HG(29.39 IN HG)
DRY BULB TEMP. 18.9 DEG C(66.0 DEG F)

RELATIVE HUMIDITY , ENGINE-65. PCT , CVS-22. PCT
ABSOLUTE HUMIDITY 9.0 GM/KG(63.2 GRAINS/LB)

NOX HUMIDITY C.F. 1.0000

BAG RESULTS	
BAG NUMBER	1
TIME SECONDS	500.0
TOTAL FLOW STD. CU. METRES(SCF)	***** (40440.)
HC SAMPLE METER/RANGE/PPM	20.0/ 2/ 20.
HC BCKGRD METER/RANGE/PPM	8.0/ 2/ 8.
CO SAMPLE METER/RANGE/PPM	19.4/13/ 18.
CO BCKGRD METER/RANGE/PPM	.5/13/ 0.
CO2 SAMPLE METER/RANGE/PCT	73.7/ 3/ 1.34
CO2 BCKGRD METER/RANGE/PCT	2.7/ 3/ .04
NOX SAMPLE METER/RANGE/PPM	85.8/ 3/ 257.
NOX BCKGRD METER/RANGE/PPM	.5/ 3/ 2.
DILUTION FACTOR	9.97
HC CONCENTRATION PPM	13.
CO CONCENTRATION PPM	17.
CO2 CONCENTRATION PCT	1.30
NOX CONCENTRATION PPM	256.1
HC MASS GRAMS	8.45
CO MASS GRAMS	22.22
CO2 MASS GRAMS	27314.4
NOX MASS GRAMS	560.81
FUEL KG (LB)	8.600 (18.96)
KW HR (HP HR)	41.00 (54.98)
BSHC G/KW HR (G/HP HR)	.21 (.15)
BSCO G/KW HR (G/HP HR)	.54 (.40)
BSCO2 G/KW HR (G/HP HR)	666.23 (496.81)
BSNOX G/KW HR (G/HP HR)	13.68 (10.20)
BSFC KG/KW HR (LB/HP HR)	.210 (.345)

TOTAL TEST RESULTS 1 BAGS

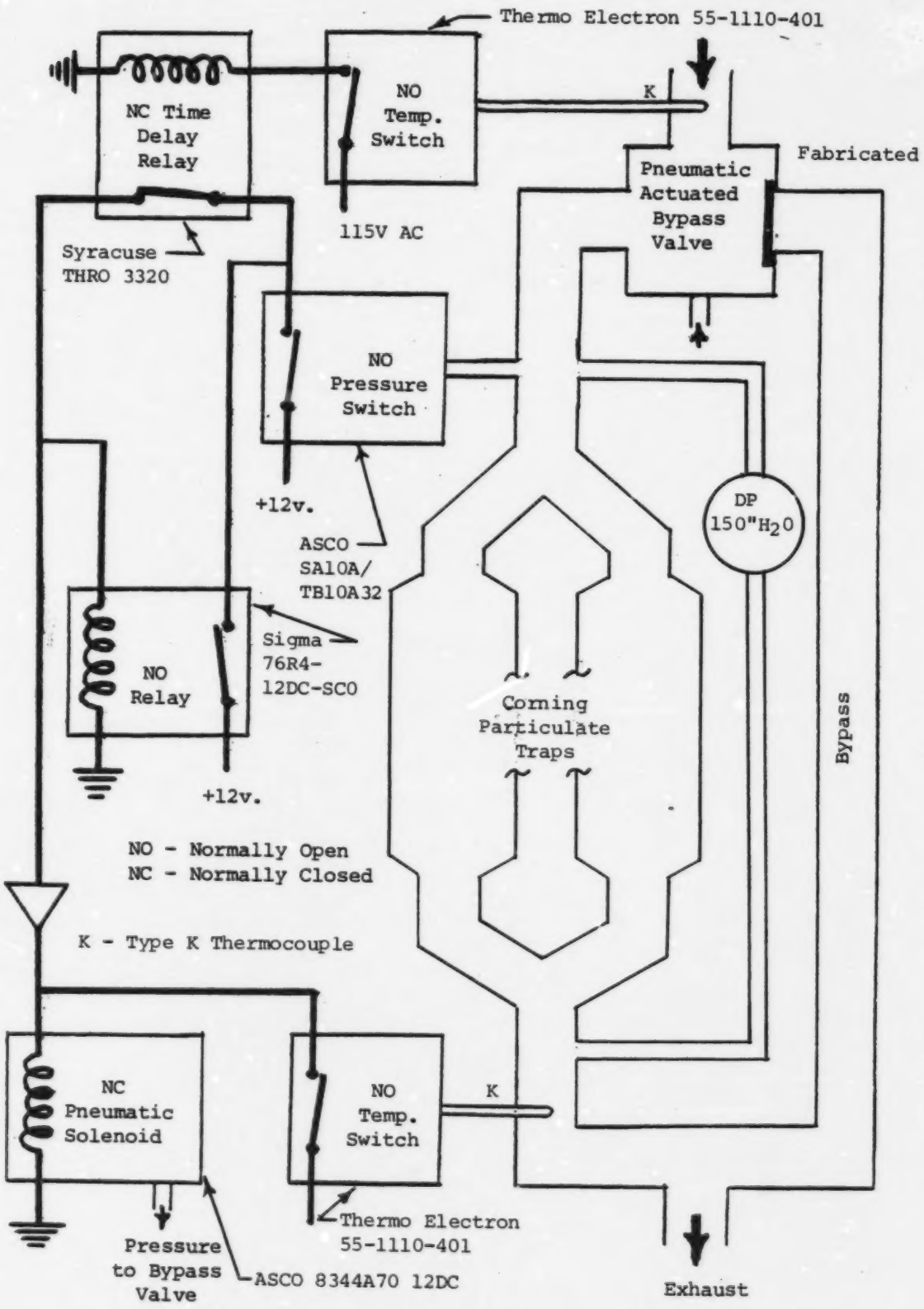
TOTAL KW HR (HP HR)	41.00 (54.98)
BSHC G/KW HR (G/HP HR)	.21 (.15)
BSCO G/KW HR (G/HP HR)	.54 (.40)
BSCO2 G/KW HR (G/HP HR)	666. (497.)
BSNOX G/KW HR (G/HP HR)	13.68 (10.20)
BSFC KG/KW HR (LB/HP HR)	.210 (.345)

PARTICULATE RESULTS, TOTAL FOR 1 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	7.32
	G/KWHR(G/HPHR)	.18 (.13)
	G/KG FUEL (G/LB FUEL)	.85 (.39)
	FILTER EFF.	94.8

APPENDIX B

PARTICULATE TRAP BYPASS SYSTEM



Schematic of particulate trap bypass system

APPENDIX C

EXHAUST PARTICULATE TRAP RESULTS

C-2 through C-19	Computer Printouts of Hot-Start Transient Tests
C-20 through C-26	Computer Printouts of Cold-Start Transient Tests

TABLE ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.BLWOH RUN3
DATE 6/ 7/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 736.60 MM HG(29.00 IN HG)
DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)

RELATIVE HUMIDITY , ENGINE-44. PCT , CVS-59. PCT
ABSOLUTE HUMIDITY 9.3 GM/KG(65.1 GRAINS/LB)

NOX HUMIDITY C.F. 1.0000

BAG RESULTS

	1	2	3	4
BAG NUMBER				
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.1	300.0	305.1	297.9
TOTAL FLOW STD. CU. METRES(SCF)	264.5 (9344.)	269.7 (9525.)	274.3 (9690.)	267.8 (9458.)
HC SAMPLE METER/RANGE/PPM	27.9/22/ 28.	30.0/22/ 30.	25.5/22/ 25.	34.5/22/ 35.
HC BCKGRD METER/RANGE/PPM	9.9/ 2/ 10.	10.0/ 2/ 10.	8.7/ 2/ 9.	8.5/ 2/ 9.
CO SAMPLE METER/RANGE/PPM	56.2/13/ 54.	51.2/12/ 109.	53.6/12/ 115.	57.5/13/ 55.
CO BCKGRD METER/RANGE/PPM	.7/13/ 1.	.1/12/ 0.	.3/12/ 1.	.1/13/ 0.
CO2 SAMPLE METER/RANGE/PCT	88.0/12/ .39	69.9/11/ .60	84.6/ 3/ 1.57	86.2/12/ .38
CO2 BCKGRD METER/RANGE/PCT	11.6/12/ .04	7.0/11/ .04	3.1/ 3/ .05	11.7/12/ .04
NOX SAMPLE METER/RANGE/PPM	85.9/ 1/ 26.	46.2/ 2/ 46.	57.1/ 3/ 171.	92.0/ 1/ 27.
NOX BCKGRD METER/RANGE/PPM	1.7/ 1/ 0.	.3/ 2/ 0.	.1/ 3/ 0.	1.2/ 1/ 0.
DILUTION FACTOR	33.61	21.70	8.49	34.45
HC CONCENTRATION PPM	18.	21.	18.	26.
CO CONCENTRATION PPM	51.	105.	109.	53.
CO2 CONCENTRATION PCT	.35	.57	1.52	.34
NOX CONCENTRATION PPM	25.1	45.9	171.0	27.0
HC MASS GRAMS	2.79	3.19	2.82	4.06
CO MASS GRAMS	15.86	33.09	34.75	16.63
CO2 MASS GRAMS	1708.4	2792.8	7654.0	1675.5
NOX MASS GRAMS	12.68	23.69	89.76	13.84
FUEL KG (LB)	.547 (1.21)	.897 (1.98)	2.425 (5.35)	.539 (1.19)
KW HR (HP HR)	1.79 (2.40)	3.21 (4.30)	10.97 (14.71)	1.86 (2.49)
BSHC G/KW HR (G/HP HR)	1.56 (1.16)	.99 (.74)	.26 (.19)	2.18 (1.63)
BSCO G/KW HR (G/HP HR)	8.86 (6.61)	10.32 (7.70)	3.17 (2.36)	8.96 (6.68)
BSCO2 G/KW HR (G/HP HR)	954.59 (711.84)	870.97 (649.48)	697.77 (520.33)	902.38 (672.90)
BSNOX G/KW HR (G/HP HR)	7.09 (5.28)	7.39 (5.51)	8.18 (6.10)	7.45 (5.56)
BSFC KG/KW HR (LB/HP HR)	.306 (.503)	.280 (.460)	.221 (.363)	.290 (.477)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	17.82 (23.90)
BSHC G/KW HR (G/HP HR)	.72 (.54)
BSCO G/KW HR (G/HP HR)	5.63 (4.20)
BSCO2 G/KW HR (G/HP HR)	776. (579.)
BSNOX G/KW HR (G/HP HR)	7.85 (5.86)
BSFC KG/KW HR (LB/HP HR)	.247 (.407)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES

GRAMS/TEST	13.17
G/KWHR(G/HPHR)	.74 (.55)
G/KG FUEL (G/LB FUEL)	2.99 (1.36)
FILTER EFF.	98.0

TABLE ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.BLWOH RUN4
DATE 6/ 7/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 736.35 MM HG(28.99 IN HG)
DRY BULB TEMP. 26.1 DEG C(79.0 DEG F)

RELATIVE HUMIDITY , ENGINE-46. PCT , CVS-59. PCT
ABSOLUTE HUMIDITY 10.1 GM/KG(70.4 GRAINS/LB)

NOX HUMIDITY C.F. 1.0000

BAG RESULTS	1	2	3	4
BAG NUMBER	NYNF	LANF	LAF	NYNF
DESCRIPTION				
TIME SECONDS	296.1	300.0	305.1	298.0
TOTAL FLOW STD. CU. METRES(SCF)	266.9 (9426.)	270.6 (9557.)	275.1 (9718.)	268.8 (9493.)
HC SAMPLE METER/RANGE/PPM	27.6/22/ 28.	28.9/22/ 29.	25.2/22/ 25.	33.5/22/ 33.
HC BCKGRD METER/RANGE/PPM	8.2/ 2/ 8.	10.0/ 2/ 10.	10.0/ 2/ 10.	10.3/ 2/ 10.
CO SAMPLE METER/RANGE/PPM	58.4/13/ 56.	50.9/12/ 108.	53.0/12/ 113.	59.8/13/ 57.
CO BCKGRD METER/RANGE/PPM	1.2/13/ 1.	.4/12/ 1.	.5/12/ 1.	.1/13/ 0.
CO2 SAMPLE METER/RANGE/PCT	88.8/12/ .40	70.5/11/ .61	85.3/ 3/ 1.58	89.8/12/ .40
CO2 BCKGRD METER/RANGE/PCT	12.0/12/ .04	7.2/11/ .04	3.1/ 3/ .05	12.1/12/ .04
NOX SAMPLE METER/RANGE/PPM	91.5/ 1/ 27.	48.2/ 2/ 48.	59.2/ 3/ 178.	29.8/ 2/ 30.
NOX BCKGRD METER/RANGE/PPM	.5/ 1/ 0.	.3/ 2/ 0.	.1/ 3/ 0.	.4/ 2/ 0.
DILUTION FACTOR	33.19	21.45	8.41	32.65
HC CONCENTRATION PPM	20.	19.	16.	24.
CO CONCENTRATION PPM	53.	104.	107.	56.
CO2 CONCENTRATION PCT	.36	.57	1.54	.36
NOX CONCENTRATION PPM	27.1	47.9	177.3	29.4
HC MASS GRAMS	3.02	3.03	2.59	3.64
CO MASS GRAMS	16.56	32.81	34.28	17.42
CO2 MASS GRAMS	1740.0	2833.6	7749.9	1780.5
NOX MASS GRAMS	13.82	24.80	93.33	15.12
FUEL KG (LB)	.558 (1.23)	.909 (2.00)	2.454 (5.41)	.572 (1.26)
KW HR (HP HR)	1.83 (2.45)	3.29 (4.41)	11.14 (14.94)	1.90 (2.55)
BSHC G/KW HR (G/HP HR)	1.65 (1.23)	.92 (.69)	.23 (.17)	1.92 (1.43)
BSCO G/KW HR (G/HP HR)	9.07 (6.76)	9.98 (7.44)	3.08 (2.29)	9.16 (6.83)
BSCO2 G/KW HR (G/HP HR)	952.39 (710.20)	861.66 (642.54)	695.63 (518.73)	936.33 (698.22)
BSNOX G/KW HR (G/HP HR)	7.57 (5.64)	7.54 (5.62)	8.38 (6.25)	7.95 (5.93)
BSFC KG/KW HR (LB/HP HR)	.305 (.502)	.277 (.455)	.220 (.362)	.301 (.494)

TOTAL TEST RESULTS 4 BAGS

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

TOTAL KW HR (HP HR)	18.16 (24.35)
BSHC G/KW HR (G/HP HR)	.68 (.50)
BSCO G/KW HR (G/HP HR)	5.57 (4.15)
BSCO2 G/KW HR (G/HP HR)	777. (579.)
BSNOX G/KW HR (G/HP HR)	8.10 (6.04)
BSFC KG/KW HR (LB/HP HR)	.247 (.407)

90MM PARTICULATE RATES

GRAMS/TEST	12.60
G/KWHR(G/HPHR)	.69 (.52)
G/KG FUEL (G/LB FUEL)	2.80 (1.27)
FILTER EFF.	97.7

TABLE

ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.RLWOH RUN5
DATE 6/11/84
TIME
DYNO NO. 5

DIESEL EM-597
BAG CART NO. 1

BAROMETER 743.46 MM HG(29.27 IN HG)
DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)

RELATIVE HUMIDITY , ENGINE-52. PCT , CVS-63. PCT
ABSOLUTE HUMIDITY 10.4 GM/KG(73.1 GRAINS/LB)

NOX HUMIDITY C.F. 1.0000

BAG RESULTS	1	2	3	4
BAG NUMBER	NYNF	LANF	LAF	NYNF
DESCRIPTION				
TIME SECONDS	297.0	299.9	305.0	297.9
TOTAL FLOW STD. CU. METRES(SCF)	269.5 (9517.)	273.1 (9647.)	277.8 (9814.)	271.2 (9580.)
HC SAMPLE METER/RANGE/PPM	32.0/22/ 32.	33.6/22/ 34.	27.1/22/ 27.	37.8/22/ 38.
HC BCKGRD METER/RANGE/PPM	12.0/ 2/ 12.	12.0/ 2/ 12.	11.8/ 2/ 12.	11.2/ 2/ 11.
CO SAMPLE METER/RANGE/PPM	65.0/13/ 63.	55.9/12/ 121.	55.8/12/ 121.	63.4/13/ 61.
CO BCKGRD METER/RANGE/PPM	1.3/13/ 1.	.1/12/ 0.	.3/12/ 1.	.1/13/ 0.
CO2 SAMPLE METER/RANGE/PCT	91.6/12/ .41	71.5/11/ .62	85.2/ 3/ 1.58	89.4/12/ .40
CO2 BCKGRD METER/RANGE/PCT	12.8/12/ .04	7.4/11/ .04	3.1/ 3/ .05	12.4/12/ .04
NOX SAMPLE METER/RANGE/PPM	90.2/ 1/ 27.	47.5/ 2/ 48.	54.5/ 3/ 164.	94.7/ 1/ 28.
NOX BCKGRD METER/RANGE/PPM	1.3/ 1/ 0.	.3/ 2/ 0.	.1/ 3/ 0.	.6/ 1/ 0.
DILUTION FACTOR	31.77	20.97	8.42	32.78
HC CONCENTRATION PPM	20.	22.	17.	27.
CO CONCENTRATION PPM	60.	117.	114.	59.
CO2 CONCENTRATION PCT	.37	.58	1.54	.36
NOX CONCENTRATION PPM	26.5	47.2	163.2	28.0
HC MASS GRAMS	3.17	3.49	2.68	4.22
CO MASS GRAMS	18.79	37.13	36.88	18.72
CO2 MASS GRAMS	1827.3	2917.3	7815.8	1779.7
NOX MASS GRAMS	13.64	24.67	86.76	14.53
FUEL KG (LB)	.586 (1.29)	.938 (2.07)	2.476 (5.46)	.573 (1.26)
KW HR (HP HR)	1.91 (2.56)	3.43 (4.60)	11.42 (15.32)	2.01 (2.70)
BSHC G/KW HR (G/HP HR)	1.66 (1.24)	1.02 (.76)	.23 (.17)	2.09 (1.56)
BSCO G/KW HR (G/HP HR)	9.84 (7.34)	10.83 (8.07)	3.23 (2.41)	9.30 (6.93)
BSCO2 G/KW HR (G/HP HR)	957.19 (713.77)	850.46 (634.19)	684.15 (510.17)	883.91 (659.13)
BSNOX G/KW HR (G/HP HR)	7.14 (5.33)	7.19 (5.36)	7.59 (5.66)	7.22 (5.38)
BSFC KG/KW HR (LB/HP HR)	.307 (.505)	.274 (.450)	.217 (.356)	.284 (.467)

C14

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	18.78 (25.18)
BSHC G/KW HR (G/HP HR)	.72 (.54)
BSCO G/KW HR (G/HP HR)	5.94 (4.43)
BSCO2 G/KW HR (G/HP HR)	764. (569.)
BSNOX G/KW HR (G/HP HR)	7.43 (5.54)
BSFC KG/KW HR (LB/HP HR)	.244 (.400)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	14.33
	G/KWHR(G/HPHR)	.76 (.57)
	G/KG FUEL (G/LB FUEL)	3.13 (1.42)
	FILTER EFF.	97.2

TABLE ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.BLWOH RUN6
DATE 6/18/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 743.46 MM HG(29.27 IN HG)
DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)

RELATIVE HUMIDITY , ENGINE-57. PCT , CVS-59. PCT
ABSOLUTE HUMIDITY 11.2 GM/KG(78.4 GRAINS/LB)

NOX HUMIDITY C.F. 1.0000

BAG RESULTS	1	2	3	4
BAG NUMBER	NYNF	LANF	LAF	NYNF
DESCRIPTION				
TIME SECONDS	296.2	300.1	305.1	298.0
TOTAL FLOW STD. CU. METRES(SCF)	268.8 (9493.)	272.3 (9617.)	276.9 (9780.)	270.4 (9551.)
HC SAMPLE METER/RANGE/PPM	28.3/22/ 28.	29.2/22/ 29.	24.7/22/ 25.	33.0/22/ 33.
HC BCKGRD METER/RANGE/PPM	10.0/ 2/ 10.	10.5/ 2/ 11.	10.0/ 2/ 10.	9.4/ 2/ 9.
CO SAMPLE METER/RANGE/PPM	52.7/13/ 50.	48.2/12/ 101.	53.1/12/ 114.	51.2/13/ 48.
CO BCKGRD METER/RANGE/PPM	.9/13/ 1.	.6/12/ 1.	.6/12/ 1.	1.3/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	89.4/12/ .40	69.2/11/ .60	82.3/ 3/ 1.52	86.4/12/ .38
CO2 BCKGRD METER/RANGE/PCT	12.5/12/ .04	7.4/11/ .04	2.7/ 3/ .04	12.0/12/ .04
NOX SAMPLE METER/RANGE/PPM	86.5/ 1/ 26.	44.6/ 2/ 45.	51.8/ 3/ 155.	90.1/ 1/ 27.
NOX BCKGRD METER/RANGE/PPM	1.0/ 1/ 0.	.3/ 2/ 0.	.1/ 3/ 0.	.7/ 1/ 0.
DILUTION FACTOR	32.94	22.04	8.75	34.42
HC CONCENTRATION PPM	19.	19.	16.	24.
CO CONCENTRATION PPM	48.	97.	107.	46.
CO2 CONCENTRATION PCT	.36	.55	1.48	.34
NOX CONCENTRATION PPM	25.4	44.3	155.1	26.6
HC MASS GRAMS	2.89	3.02	2.53	3.72
CO MASS GRAMS	14.96	30.87	34.57	14.49
CO2 MASS GRAMS	1761.6	2765.0	7509.6	1692.7
NOX MASS GRAMS	13.08	23.08	82.17	13.76
FUEL KG (LB)	.564 (1.24)	.887 (1.96)	2.379 (5.24)	.543 (1.20)
KW HR (HP HR)	1.84 (2.47)	3.29 (4.41)	10.85 (14.55)	1.95 (2.62)
BSHC G/KW HR (G/HP HR)	1.57 (1.17)	.92 (.68)	.23 (.17)	1.90 (1.42)
BSCO G/KW HR (G/HP HR)	8.12 (6.06)	9.39 (7.00)	3.19 (2.38)	7.41 (5.53)
BSCO2 G/KW HR (G/HP HR)	956.44 (713.21)	840.80 (626.98)	692.13 (516.12)	866.38 (646.06)
BSNOX G/KW HR (G/HP HR)	7.10 (5.30)	7.02 (5.23)	7.57 (5.65)	7.04 (5.25)
BSFC KG/KW HR (LB/HP HR)	.306 (.503)	.270 (.443)	.219 (.360)	.278 (.457)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	17.93 (24.05)
BSHC G/KW HR (G/HP HR)	.68 (.51)
BSCO G/KW HR (G/HP HR)	5.29 (3.95)
BSCO2 G/KW HR (G/HP HR)	766. (571.)
BSNOX G/KW HR (G/HP HR)	7.37 (5.49)
BSFC KG/KW HR (LB/HP HR)	.244 (.401)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	
GRAMS/TEST	12.98
G/KWHR(G/HPHR)	.72 (.54)
G/KG FUEL (G/LB FUEL)	2.97 (1.35)
FILTER EFF.	98.0

TABLE ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.BLWTH RUN1
DATE 6/ 7/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 738.63 MM HG(29.08 IN HG)
DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)

RELATIVE HUMIDITY , ENGINE-47. PCT , CVS-65. PCT
ABSOLUTE HUMIDITY 9.6 GM/KG(67.1 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

	1	2	3	4
BAG NUMBER				
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	300.0	305.1	297.9
TOTAL FLOW STD. CU. METRES(SCF)	267.9 (9464.)	271.7 (9595.)	276.2 (9756.)	269.7 (9525.)
HC SAMPLE METER/RANGE/PPM	27.3/22/ 27.	32.5/22/ 32.	18.9/22/ 19.	27.0/22/ 27.
HC BCKGRD METER/RANGE/PPM	9.4/ 2/ 9.	13.4/ 2/ 13.	13.2/ 2/ 13.	13.5/ 2/ 14.
CO SAMPLE METER/RANGE/PPM	39.7/13/ 37.	69.5/13/ 68.	88.4/12/ 216.	39.1/13/ 36.
CO BCKGRD METER/RANGE/PPM	.1/13/ 0.	.4/13/ 0.	.1/12/ 0.	.8/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	84.1/12/ .37	63.0/11/ .52	79.5/ 3/ 1.46	81.4/12/ .35
CO2 BCKGRD METER/RANGE/PCT	11.9/12/ .04	7.1/11/ .04	3.4/ 3/ .05	12.9/12/ .04
NOX SAMPLE METER/RANGE/PPM	73.8/ 1/ 22.	32.4/ 2/ 32.	38.2/ 3/ 115.	76.6/ 1/ 23.
NOX BCKGRD METER/RANGE/PPM	.8/ 1/ 0.	.1/ 2/ 0.	.1/ 3/ 0.	.9/ 1/ 0.
DILUTION FACTOR	35.80	25.21	9.04	37.33
HC CONCENTRATION PPM	18.	20.	7.	14.
CO CONCENTRATION PPM	36.	65.	205.	35.
CO2 CONCENTRATION PCT	.33	.48	1.41	.31
NOX CONCENTRATION PPM	21.7	32.3	114.3	22.5
HC MASS GRAMS	2.81	3.08	1.14	2.16
CO MASS GRAMS	11.17	20.62	66.00	10.88
CO2 MASS GRAMS	1613.2	2400.4	7147.8	1530.6
NOX MASS GRAMS	11.13	16.79	60.41	11.62
FUEL KG (LB)	.515 (1.14)	.767 (1.69)	2.279 (5.02)	.488 (1.08)
KW HR (HP HR)	1.54 (2.06)	2.46 (3.30)	9.25 (12.41)	1.54 (2.07)
BSHC G/KW HR (G/HP HR)	1.83 (1.36)	1.25 (.93)	.12 (.09)	1.40 (1.04)
BSCO G/KW HR (G/HP HR)	7.27 (5.42)	8.38 (6.25)	7.13 (5.32)	7.05 (5.26)
BSCO2 G/KW HR (G/HP HR)	1050.19 (783.13)	975.44 (727.38)	772.39 (575.97)	991.59 (739.43)
BSNOX G/KW HR (G/HP HR)	7.25 (5.40)	6.82 (5.09)	6.53 (4.87)	7.53 (5.61)
BSFC KG/KW HR (LB/HP HR)	.335 (.551)	.312 (.513)	.246 (.405)	.316 (.520)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	14.79 (19.84)
BSHC G/KW HR (G/HP HR)	.62 (.46)
BSCO G/KW HR (G/HP HR)	7.35 (5.48)
BSCO2 G/KW HR (G/HP HR)	858. (640.)
BSNOX G/KW HR (G/HP HR)	6.76 (5.04)
BSFC KG/KW HR (LB/HP HR)	.274 (.450)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	1.45
	G/KWHR(G/HPHR)	.10 (.07)
	G/KG FUEL (G/LB FUEL)	.36 (.16)
	FILTER EFF.	84.0

TABLE ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.BLWTH RUN2
DATE 6/ 7/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 737.87 MM HG(29.05 IN HG)
DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)

RELATIVE HUMIDITY , ENGINE-46. PCT , CVS-60. PCT
ABSOLUTE HUMIDITY 9.7 GM/KG(67.9 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

	1	2	3	4
BAG NUMBER				
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	300.0	305.0	297.9
TOTAL FLOW STD. CU. METRES(SCF)	267.4 (9443.)	271.1 (9577.)	275.6 (9736.)	269.2 (9508.)
HC SAMPLE METER/RANGE/PPM	24.4/22/ 24.	28.1/22/ 28.	16.1/22/ 16.	24.2/22/ 24.
HC BCKGRD METER/RANGE/PPM	11.5/ 2/ 12.	11.5/ 2/ 12.	9.5/ 2/ 10.	9.1/ 2/ 9.
CO SAMPLE METER/RANGE/PPM	45.0/13/ 42.	76.6/13/ 75.	87.0/12/ 211.	37.0/13/ 34.
CO BCKGRD METER/RANGE/PPM	1.3/13/ 1.	1.1/13/ 1.	.2/12/ 0.	1.1/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	82.5/12/ .36	63.5/11/ .53	78.4/ 3/ 1.44	80.0/12/ .34
CO2 BCKGRD METER/RANGE/PCT	12.8/12/ .04	7.3/11/ .04	3.2/ 3/ .05	12.4/12/ .04
NOX SAMPLE METER/RANGE/PPM	77.0/ 1/ 23.	34.9/ 2/ 35.	39.9/ 3/ 120.	77.3/ 1/ 23.
NOX BCKGRD METER/RANGE/PPM	.7/ 1/ 0.	.3/ 2/ 0.	.1/ 3/ 0.	.9/ 1/ 0.
DILUTION FACTOR	36.67	24.93	9.19	38.22
HC CONCENTRATION PPM	13.	17.	8.	15.
CO CONCENTRATION PPM	40.	72.	201.	32.
CO2 CONCENTRATION PCT	.32	.49	1.39	.30
NOX CONCENTRATION PPM	22.7	34.6	119.4	22.7
HC MASS GRAMS	2.03	2.67	1.21	2.38
CO MASS GRAMS	12.43	22.80	64.55	10.17
CO2 MASS GRAMS	1549.7	2418.5	7031.4	1497.8
NOX MASS GRAMS	11.61	17.95	62.98	11.71
FUEL KG (LB)	.495 (1.09)	.774 (1.71)	2.242 (4.94)	.478 (1.05)
KW HR (HP HR)	1.54 (2.06)	2.56 (3.43)	9.30 (12.47)	1.55 (2.08)
BSHC G/KW HR (G/HP HR)	1.32 (.99)	1.04 (.78)	.13 (.10)	1.53 (1.14)
BSCO G/KW HR (G/HP HR)	8.09 (6.03)	8.92 (6.65)	6.94 (5.18)	6.56 (4.89)
BSCO2 G/KW HR (G/HP HR)	1008.84 (752.29)	945.55 (705.10)	756.15 (563.86)	965.68 (720.11)
BSNOX G/KW HR (G/HP HR)	7.56 (5.64)	7.02 (5.23)	6.77 (5.05)	7.55 (5.63)
BSFC KG/KW HR (LB/HP HR)	.322 (.530)	.302 (.497)	.241 (.396)	.308 (.507)

TOTAL TEST RESULTS 4 BAGS

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

TOTAL KW HR (HP HR)	14.94 (20.04)	
BSHC G/KW HR (G/HP HR)	.55 (.41)	
BSCO G/KW HR (G/HP HR)	7.36 (5.49)	
BSCO2 G/KW HR (G/HP HR)	836. (624.)	
BSNOX G/KW HR (G/HP HR)	6.98 (5.20)	
BSFC KG/KW HR (LB/HP HR)	.267 (.439)	
90MM PARTICULATE RATES	GRAMS/TEST	1.13
	G/KWHR(G/HPHR)	.08 (.06)
	G/KG FUEL (G/LB FUEL)	.28 (.13)
	FILTER EFF.	79.2

TABLE ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.BLWTH RUN3
DATE 6/ 8/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 739.90 MM HG(29.13 IN HG)
DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)

RELATIVE HUMIDITY , ENGINE-58. PCT , CVS-59. PCT
ABSOLUTE HUMIDITY 11.5 GM/KG(80.2 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

	1	2	3	4
BAG NUMBER				
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.0	300.0	305.0	297.9
TOTAL FLOW STD. CU. METRES(SCF)	268.7 (9491.)	272.3 (9618.)	276.8 (9776.)	270.4 (9549.)
HC SAMPLE METER/RANGE/PPM	28.4/22/ 28.	30.9/22/ 31.	17.5/22/ 18.	25.8/22/ 26.
HC BCKGRD METER/RANGE/PPM	8.8/ 2/ 9.	11.5/ 2/ 12.	11.2/ 2/ 11.	10.9/ 2/ 11.
CO SAMPLE METER/RANGE/PPM	44.1/13/ 41.	72.0/13/ 70.	89.4/12/ 219.	36.7/13/ 34.
CO BCKGRD METER/RANGE/PPM	1.3/13/ 1.	1.9/13/ 2.	.8/12/ 1.	.9/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	84.3/12/ .37	62.7/11/ .52	79.9/ 3/ 1.47	81.1/12/ .35
CO2 BCKGRD METER/RANGE/PCT	11.7/12/ .04	6.9/11/ .04	3.1/ 3/ .05	12.0/12/ .04
NOX SAMPLE METER/RANGE/PPM	74.6/ 1/ 22.	33.6/ 2/ 34.	40.0/ 3/ 120.	77.2/ 1/ 23.
NOX BCKGRD METER/RANGE/PPM	.9/ 1/ 0.	.2/ 2/ 0.	.1/ 3/ 0.	.5/ 1/ 0.
DILUTION FACTOR	35.64	25.37	8.99	37.55
HC CONCENTRATION PPM	20.	20.	8.	15.
CO CONCENTRATION PPM	39.	67.	208.	32.
CO2 CONCENTRATION PCT	.33	.48	1.43	.31
NOX CONCENTRATION PPM	21.9	33.4	119.7	22.8
HC MASS GRAMS	3.07	3.11	1.21	2.37
CO MASS GRAMS	12.22	21.14	66.92	10.19
CO2 MASS GRAMS	1627.0	2394.7	7225.7	1541.7
NOX MASS GRAMS	11.27	17.40	63.40	11.80
FUEL KG (LB)	.520 (1.15)	.766 (1.69)	2.304 (5.08)	.492 (1.08)
KW HR (HP HR)	1.53 (2.05)	2.48 (3.33)	9.31 (12.49)	1.55 (2.08)
BSHC G/KW HR (G/HP HR)	2.01 (1.50)	1.25 (.93)	.13 (.10)	1.53 (1.14)
BSCO G/KW HR (G/HP HR)	8.00 (5.96)	8.51 (6.35)	7.18 (5.36)	6.57 (4.90)
BSCO2 G/KW HR (G/HP HR)	1064.30 (793.65)	964.38 (719.14)	775.81 (578.52)	993.95 (741.19)
BSNOX G/KW HR (G/HP HR)	7.37 (5.50)	7.01 (5.23)	6.81 (5.08)	7.61 (5.67)
BSFC KG/KW HR (LB/HP HR)	.340 (.559)	.308 (.507)	.247 (.407)	.317 (.521)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	14.88 (19.95)
BSHC G/KW HR (G/HP HR)	.66 (.49)
BSCO G/KW HR (G/HP HR)	7.43 (5.54)
BSCO2 G/KW HR (G/HP HR)	860. (641.)
BSNOX G/KW HR (G/HP HR)	6.98 (5.21)
BSFC KG/KW HR (LB/HP HR)	.274 (.451)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	1.64
	G/KWHR(G/HPHR)	.11 (.08)
	G/KG FUEL (G/LB FUEL)	.40 (.18)
	FILTER EFF.	81.3

TABLE ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.BLWTH RUN4
DATE 6/18/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 742.19 MM HG(29.22 IN HG)
DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)

RELATIVE HUMIDITY , ENGINE-59. PCT , CVS-59. PCT
ABSOLUTE HUMIDITY 11.6 GM/KG(81.3 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS	1	2	3	4
BAG NUMBER	NYNF	LANF	LAF	NYNF
DESCRIPTION	296.0	300.0	305.0	297.7
TIME SECONDS	268.9 (9498.)	272.5 (9626.)	277.1 (9788.)	270.5 (9556.)
TOTAL FLOW STD. CU. METRES(SCF)				
HC SAMPLE METER/RANGE/PPM	28.8/22/ 29.	32.8/22/ 33.	17.7/22/ 18.	26.0/22/ 26.
HC BCKGRD METER/RANGE/PPM	10.5/ 2/ 11.	10.4/ 2/ 10.	9.2/ 2/ 9.	9.2/ 2/ 9.
CO SAMPLE METER/RANGE/PPM	42.8/13/ 40.	67.8/13/ 66.	89.0/12/ 218.	39.4/13/ 37.
CO BCKGRD METER/RANGE/PPM	1.6/13/ 1.	1.2/13/ 1.	.6/12/ 1.	1.4/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	83.0/12/ .36	62.7/11/ .52	79.0/ 3/ 1.45	80.6/12/ .35
CO2 BCKGRD METER/RANGE/PCT	12.3/12/ .04	7.1/11/ .04	3.1/ 3/ .05	12.3/12/ .04
NOX SAMPLE METER/RANGE/PPM	76.6/ 1/ 23.	33.9/ 2/ 34.	40.2/ 3/ 121.	77.1/ 1/ 23.
NOX BCKGRD METER/RANGE/PPM	.3/ 1/ 0.	.1/ 2/ 0.	.1/ 3/ 0.	.5/ 1/ 0.
DILUTION FACTOR	36.36	25.38	9.11	37.81
HC CONCENTRATION PPM	19.	23.	9.	17.
CO CONCENTRATION PPM	38.	63.	207.	34.
CO2 CONCENTRATION PCT	.32	.48	1.41	.31
NOX CONCENTRATION PPM	22.7	33.8	120.3	22.8
HC MASS GRAMS	2.89	3.59	1.51	2.66
CO MASS GRAMS	11.76	19.94	66.72	10.86
CO2 MASS GRAMS	1581.3	2390.8	7139.1	1523.7
NOX MASS GRAMS	11.68	17.62	63.79	11.80
FUEL KG (LB)	.505 (1.11)	.765 (1.69)	2.277 (5.02)	.487 (1.07)
KW HR (HP HR)	1.59 (2.13)	2.54 (3.40)	9.48 (12.71)	1.60 (2.14)
BSHC G/KW HR (G/HP HR)	1.82 (1.36)	1.42 (1.06)	.16 (.12)	1.66 (1.24)
BSCO G/KW HR (G/HP HR)	7.40 (5.52)	7.87 (5.87)	7.04 (5.25)	6.81 (5.08)
BSCO2 G/KW HR (G/HP HR)	995.59 (742.41)	942.99 (703.19)	753.24 (561.69)	954.81 (712.00)
BSNOX G/KW HR (G/HP HR)	7.35 (5.48)	6.95 (5.18)	6.73 (5.02)	7.39 (5.51)
BSFC KG/KW HR (LB/HP HR)	.318 (.523)	.302 (.496)	.240 (.395)	.305 (.501)

C-9

TOTAL TEST RESULTS 4 BAGS

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

TOTAL KW HR (HP HR)	15.20 (20.38)	
BSHC G/KW HR (G/HP HR)	.70 (.52)	
BSCO G/KW HR (G/HP HR)	7.19 (5.36)	
BSCO2 G/KW HR (G/HP HR)	831. (620.)	
BSNOX G/KW HR (G/HP HR)	6.90 (5.15)	
BSFC KG/KW HR (LB/HP HR)	.265 (.436)	
90MM PARTICULATE RATES	GRAMS/TEST	1.65
	G/KWHR(G/HPHR)	.11 (.08)
	G/KG FUEL (G/LB FUEL)	.41 (.19)
	FILTER EFF.	79.0

TABLE ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-40
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.BLDT RUN2
DATE 6/20/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 743.46 MM HG(29.27 IN HG)
DRY BULB TEMP. 23.3 DEG C(74.0 DEG F)

RELATIVE HUMIDITY , ENGINE-58. PCT , CVS-62. PCT
ABSOLUTE HUMIDITY 10.6 GM/KG(73.9 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS	1 NYNF	2 LANF	3 LAF	4 NYNF
TIME SECONDS	296.1	300.1	305.2	298.1
TOTAL FLOW STD. CU. METRES(SCF)	270.0 (9537.)	273.7 (9667.)	278.4 (9832.)	271.9 (9602.)
HC SAMPLE METER/RANGE/PPM	28.3/22/ 28.	29.9/22/ 30.	22.7/22/ 23.	31.8/22/ 32.
HC BCKGRD METER/RANGE/PPM	10.0/ 2/ 10.	10.0/ 2/ 10.	8.7/ 2/ 9.	8.5/ 2/ 9.
CO SAMPLE METER/RANGE/PPM	47.8/13/ 45.	49.6/12/ 105.	68.8/12/ 156.	48.9/13/ 46.
CO BCKGRD METER/RANGE/PPM	.3/13/ 0.	.3/12/ 1.	.1/12/ 0.	.5/13/ 0.
CO2 SAMPLE METER/RANGE/PCT	87.0/12/ .38	67.9/11/ .58	81.0/ 3/ 1.49	86.4/12/ .38
CO2 BCKGRD METER/RANGE/PCT	12.9/12/ .04	7.4/11/ .04	3.2/ 3/ .05	12.6/12/ .04
NOX SAMPLE METER/RANGE/PPM	81.5/ 1/ 24.	40.3/ 2/ 40.	48.8/ 3/ 146.	88.0/ 1/ 26.
NOX BCKGRD METER/RANGE/PPM	1.2/ 1/ 0.	.4/ 2/ 0.	.1/ 3/ 0.	.9/ 1/ 0.
DILUTION FACTOR	34.18	22.61	8.89	34.45
HC CONCENTRATION PPM	19.	20.	15.	24.
CO CONCENTRATION PPM	43.	101.	148.	44.
CO2 CONCENTRATION PCT	.34	.54	1.45	.34
NOX CONCENTRATION PPM	23.9	39.9	146.1	25.9
HC MASS GRAMS	2.89	3.21	2.41	3.70
CO MASS GRAMS	13.67	32.23	47.99	14.05
CO2 MASS GRAMS	1692.2	2699.7	7376.7	1691.4
NOX MASS GRAMS	12.34	20.90	77.82	13.48
FUEL KG (LB)	.541 (1.19)	.867 (1.91)	2.344 (5.17)	.542 (1.19)
KW HR (HP HR)	1.85 (2.48)	3.15 (4.23)	10.85 (14.55)	1.95 (2.61)
BSHC G/KW HR (G/HP HR)	1.56 (1.16)	1.02 (.76)	.22 (.17)	1.90 (1.42)
BSCO G/KW HR (G/HP HR)	7.39 (5.51)	10.22 (7.62)	4.42 (3.30)	7.22 (5.38)
BSCO2 G/KW HR (G/HP HR)	915.05 (682.36)	855.87 (638.22)	679.88 (506.99)	869.03 (648.03)
BSNOX G/KW HR (G/HP HR)	6.68 (4.98)	6.63 (4.94)	7.17 (5.35)	6.93 (5.16)
BSFC KG/KW HR (LB/HP HR)	.293 (.481)	.275 (.452)	.216 (.355)	.278 (.458)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	17.80 (23.87)
BSHC G/KW HR (G/HP HR)	.69 (.51)
BSCO G/KW HR (G/HP HR)	6.06 (4.52)
BSCO2 G/KW HR (G/HP HR)	756. (564.)
BSNOX G/KW HR (G/HP HR)	7.00 (5.22)
BSFC KG/KW HR (LB/HP HR)	.241 (.397)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	14.16
	G/KWHR(G/HPHR)	.80 (.59)
	G/KG FUEL (G/LB FUEL)	3.30 (1.50)
	FILTER EFF.	98.4

TABLE ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.RBLH RUN2
DATE 6/22/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 742.44 MM HG(29.23 IN HG)
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)

RELATIVE HUMIDITY , ENGINE-56. PCT , CVS-58. PCT
ABSOLUTE HUMIDITY 10.6 GM/KG(73.9 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS	1	2	3	4
BAG NUMBER	NYNF	LANF	LAF	NYNF
DESCRIPTION				
TIME SECONDS	296.0	300.0	305.0	298.0
TOTAL FLOW STD. CU. METRES(SCF)	269.1 (9506.)	272.8 (9634.)	277.3 (9796.)	270.9 (9568.)
HC SAMPLE METER/RANGE/PPM	27.6/22/ 28.	33.2/22/ 33.	29.4/22/ 29.	34.5/22/ 34.
HC BCKGRD METER/RANGE/PPM	8.0/ 2/ 8.	9.2/ 2/ 9.	9.3/ 2/ 9.	9.0/ 2/ 9.
CO SAMPLE METER/RANGE/PPM	75.1/13/ 74.	79.6/13/ 79.	77.0/13/ 76.	67.8/13/ 66.
CO BCKGRD METER/RANGE/PPM	1.3/13/ 1.	1.5/13/ 1.	1.5/13/ 1.	1.7/13/ 2.
CO2 SAMPLE METER/RANGE/PCT	94.0/12/ .43	71.2/11/ .62	84.9/ 3/ 1.57	91.6/12/ .41
CO2 BCKGRD METER/RANGE/PCT	12.6/12/ .04	7.4/11/ .04	2.9/ 3/ .04	12.3/12/ .04
NOX SAMPLE METER/RANGE/PPM	32.3/ 2/ 32.	54.1/ 2/ 54.	58.7/ 3/ 176.	33.8/ 2/ 34.
NOX BCKGRD METER/RANGE/PPM	.5/ 2/ 1.	.7/ 2/ 1.	.1/ 3/ 0.	.3/ 2/ 0.
DILUTION FACTOR	30.64	21.23	8.47	31.73
HC CONCENTRATION PPM	20.	24.	21.	26.
CO CONCENTRATION PPM	71.	75.	71.	63.
CO2 CONCENTRATION PCT	.39	.58	1.53	.37
NOX CONCENTRATION PPM	31.8	53.4	175.8	33.5
HC MASS GRAMS	3.08	3.85	3.39	4.02
CO MASS GRAMS	22.13	23.84	22.91	19.73
CO2 MASS GRAMS	1902.2	2894.4	7783.4	1845.5
NOX MASS GRAMS	16.38	27.88	93.29	17.36
FUEL KG (LB)	.612 (1.35)	.925 (2.04)	2.460 (5.42)	.594 (1.31)
KW HR (HP HR)	2.21 (2.97)	3.53 (4.73)	11.23 (15.06)	2.23 (2.99)
BSHC G/KW HR (G/HP HR)	1.39 (1.04)	1.09 (.81)	.30 (.23)	1.80 (1.34)
BSCO G/KW HR (G/HP HR)	9.99 (7.45)	6.76 (5.04)	2.04 (1.52)	8.85 (6.60)
BSCO2 G/KW HR (G/HP HR)	858.89 (640.47)	820.60 (611.92)	693.07 (516.82)	827.70 (617.22)
BSNOX G/KW HR (G/HP HR)	7.40 (5.52)	7.90 (5.89)	8.31 (6.19)	7.79 (5.81)
BSFC KG/KW HR (LB/HP HR)	.276 (.454)	.262 (.431)	.219 (.360)	.266 (.438)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	19.20 (25.75)
BSHC G/KW HR (G/HP HR)	.75 (.56)
BSCO G/KW HR (G/HP HR)	4.61 (3.44)
BSCO2 G/KW HR (G/HP HR)	751. (560.)
BSNOX G/KW HR (G/HP HR)	8.07 (6.02)
BSFC KG/KW HR (LB/HP HR)	.239 (.393)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	10.80
	G/KWHR(G/HPHR)	.56 (.42)
	G/KG FUEL (G/LB FUEL)	2.35 (1.07)
	FILTER EFF.	97.0

TABLE ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.BLSTH RUN1
DATE 7/ 2/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 740.92 MM HG(29.17 IN HG)
DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)

RELATIVE HUMIDITY , ENGINE-47. PCT , CVS-54. PCT
ABSOLUTE HUMIDITY 9.6 GM/KG(66.9 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS	1 NYNF	2 LANF	3 LAF	4 NYNF
BAG NUMBER				
DESCRIPTION				
TIME SECONDS	296.1	300.1	305.1	298.9
TOTAL FLOW STD. CU. METRES(SCF)	268.9 (9498.)	272.5 (9624.)	277.1 (9787.)	270.5 (9553.)
HC SAMPLE METER/RANGE/PPM	28.4/22/ 28.	29.4/22/ 29.	16.8/22/ 17.	26.2/22/ 26.
HC BCKGRD METER/RANGE/PPM	9.2/ 2/ 9.	8.8/ 2/ 9.	7.3/ 2/ 7.	6.9/ 2/ 7.
CO SAMPLE METER/RANGE/PPM	49.8/13/ 47.	92.6/13/ 94.	82.7/12/ 198.	45.9/13/ 43.
CO BCKGRD METER/RANGE/PPM	1.1/13/ 1.	.7/13/ 1.	.1/12/ 0.	.6/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	84.7/12/ .37	65.6/11/ .55	82.2/ 3/ 1.52	84.8/12/ .37
CO2 BCKGRD METER/RANGE/PCT	12.2/12/ .04	7.2/11/ .04	3.3/ 3/ .05	12.2/12/ .04
NOX SAMPLE METER/RANGE/PPM	78.0/ 1/ 23.	35.1/ 2/ 35.	50.8/ 3/ 152.	85.0/ 1/ 25.
NOX BCKGRD METER/RANGE/PPM	.3/ 1/ 0.	.1/ 2/ 0.	.1/ 3/ 0.	.5/ 1/ 0.
DILUTION FACTOR	35.37	23.76	8.72	35.37
HC CONCENTRATION PPM	19.	21.	10.	20.
CO CONCENTRATION PPM	45.	90.	188.	41.
CO2 CONCENTRATION PCT	.33	.51	1.47	.33
NOX CONCENTRATION PPM	23.1	35.0	152.1	25.1
HC MASS GRAMS	3.01	3.30	1.64	3.04
CO MASS GRAMS	14.05	28.65	60.71	13.06
CO2 MASS GRAMS	1631.0	2555.8	7462.5	1643.4
NOX MASS GRAMS	11.89	18.24	80.64	13.01
FUEL KG (LB)	.522 (1.15)	.820 (1.81)	2.376 (5.24)	.526 (1.16)
KW HR (HP HR)	1.74 (2.34)	2.76 (3.70)	10.34 (13.87)	1.81 (2.43)
BSHC G/KW HR (G/HP HR)	1.73 (1.29)	1.20 (.89)	.16 (.12)	1.68 (1.25)
BSCO G/KW HR (G/HP HR)	8.05 (6.00)	10.38 (7.74)	5.87 (4.38)	7.21 (5.38)
BSCO2 G/KW HR (G/HP HR)	934.71 (697.01)	926.31 (690.75)	721.51 (538.03)	906.93 (676.30)
BSNOX G/KW HR (G/HP HR)	6.81 (5.08)	6.61 (4.93)	7.80 (5.81)	7.18 (5.35)
BSFC KG/KW HR (LB/HP HR)	.299 (.492)	.297 (.489)	.230 (.378)	.290 (.477)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.66 (22.34)
BSHC G/KW HR (G/HP HR)	.66 (.49)
BSCO G/KW HR (G/HP HR)	6.99 (5.21)
BSCO2 G/KW HR (G/HP HR)	798. (595.)
BSNOX G/KW HR (G/HP HR)	7.43 (5.54)
BSFC KG/KW HR (LB/HP HR)	.255 (.419)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	1.58
	G/KWHR(G/HPHR)	.10 (.07)
	G/KG FUEL (G/LB FUEL)	.37 (.17)
	FILTER EFF.	74.5

TABLE ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.BLSTH RUN2
DATE 7/ 2/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 740.41 MM HG(29.15 IN HG)
DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)

RELATIVE HUMIDITY , ENGINE-48. PCT , CVS-54. PCT
ABSOLUTE HUMIDITY 9.8 GM/KG(68.4 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS	1	2	3	4
BAG NUMBER	NYNF	LANF	LAF	NYNF
DESCRIPTION				
TIME SECONDS	296.1	300.1	305.1	298.0
TOTAL FLOW STD. CU. METRES(SCF)	267.9 (9462.)	271.5 (9591.)	276.1 (9752.)	269.6 (9522.)
HC SAMPLE METER/RANGE/PPM	25.6/22/ 26.	26.8/22/ 27.	15.2/22/ 15.	24.4/22/ 24.
HC BCKGRD METER/RANGE/PPM	6.2/ 2/ 6.	7.5/ 2/ 8.	7.7/ 2/ 8.	7.8/ 2/ 8.
CO SAMPLE METER/RANGE/PPM	49.4/13/ 47.	91.6/13/ 92.	84.2/12/ 202.	45.2/13/ 42.
CO BCKGRD METER/RANGE/PPM	.1/13/ 0.	.8/13/ 1.	.1/12/ 0.	.7/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	84.9/12/ .37	65.4/11/ .55	82.4/ 3/ 1.52	83.5/12/ .36
CO2 BCKGRD METER/RANGE/PCT	12.0/12/ .04	6.9/11/ .04	3.2/ 3/ .05	12.3/12/ .04
NOX SAMPLE METER/RANGE/PPM	80.0/ 1/ 24.	35.8/ 2/ 36.	51.7/ 3/ 155.	81.9/ 1/ 24.
NOX BCKGRD METER/RANGE/PPM	.5/ 1/ 0.	.1/ 2/ 0.	.1/ 3/ 0.	.7/ 1/ 0.
DILUTION FACTOR	35.29	23.88	8.70	36.11
HC CONCENTRATION PPM	20.	20.	8.	17.
CO CONCENTRATION PPM	45.	89.	193.	41.
CO2 CONCENTRATION PCT	.33	.51	1.48	.32
NOX CONCENTRATION PPM	23.7	35.7	154.8	24.2
HC MASS GRAMS	3.03	3.07	1.34	2.62
CO MASS GRAMS	14.14	28.17	61.95	12.78
CO2 MASS GRAMS	1634.0	2544.0	7463.8	1599.3
NOX MASS GRAMS	12.12	18.55	81.78	12.46
FUEL KG (LB)	.523 (1.15)	.816 (1.80)	2.377 (5.24)	.511 (1.13)
KW HR (HP HR)	1.77 (2.37)	2.77 (3.71)	10.34 (13.87)	2.55 (3.42)
BSHC G/KW HR (G/HP HR)	1.71 (1.28)	1.11 (.83)	.13 (.10)	1.03 (.76)
BSCO G/KW HR (G/HP HR)	8.00 (5.97)	10.18 (7.59)	5.99 (4.47)	5.01 (3.74)
BSCO2 G/KW HR (G/HP HR)	924.55 (689.44)	919.55 (685.71)	721.64 (538.13)	627.11 (467.64)
BSNOX G/KW HR (G/HP HR)	6.86 (5.11)	6.70 (5.00)	7.91 (5.90)	4.89 (3.64)
BSFC KG/KW HR (LB/HP HR)	.296 (.487)	.295 (.485)	.230 (.378)	.201 (.330)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	17.43 (23.37)
BSHC G/KW HR (G/HP HR)	.58 (.43)
BSCO G/KW HR (G/HP HR)	6.72 (5.01)
BSCO2 G/KW HR (G/HP HR)	760. (567.)
BSNOX G/KW HR (G/HP HR)	7.17 (5.34)
BSFC KG/KW HR (LB/HP HR)	.243 (.399)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	1.39
	G/KWHR(G/HPHR)	.08 (.06)
	G/KG FUEL (G/LB FUEL)	.33 (.15)
	FILTER EFF.	77.5

TABLE ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.JMBLH RUN1
DATE 7/11/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 742.70 MM HG(29.24 IN HG)
DRY BULB TEMP. 21.7 DEG C(71.0 DEG F)

RELATIVE HUMIDITY , ENGINE-68. PCT , CVS-62. PCT
ABSOLUTE HUMIDITY 11.2 GM/KG(78.6 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

	1	2	3	4
BAG NUMBER				
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.1	300.0	305.1	298.0
TOTAL FLOW STD. CU. METRES(SCF)	269.3 (9513.)	272.9 (9639.)	277.5 (9802.)	271.1 (9574.)
HC SAMPLE METER/RANGE/PPM	16.5/22/ 16.	19.3/22/ 19.	15.2/22/ 15.	11.7/22/ 12.
HC BCKGRD METER/RANGE/PPM	12.5/ 2/ 13.	13.5/ 2/ 14.	13.7/ 2/ 14.	11.8/ 2/ 12.
CO SAMPLE METER/RANGE/PPM	79.6/13/ 79.	80.6/13/ 80.	73.9/13/ 72.	65.5/13/ 63.
CO BCKGRD METER/RANGE/PPM	.6/13/ 1.	.6/13/ 1.	1.1/13/ 1.	1.1/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	98.0/12/ .45	72.7/11/ .64	84.9/ 3/ 1.57	96.1/12/ .44
CO2 BCKGRD METER/RANGE/PCT	14.2/12/ .05	8.6/11/ .05	3.6/ 3/ .06	14.7/12/ .05
NOX SAMPLE METER/RANGE/PPM	33.0/ 2/ 33.	52.8/ 2/ 53.	53.0/ 3/ 159.	34.3/ 2/ 34.
NOX BCKGRD METER/RANGE/PPM	.6/ 2/ 1.	.7/ 2/ 1.	.1/ 3/ 0.	.5/ 2/ 1.
DILUTION FACTOR	28.99	20.65	8.48	29.91
HC CONCENTRATION PPM	4.	6.	3.	0.
CO CONCENTRATION PPM	76.	77.	68.	61.
CO2 CONCENTRATION PCT	.41	.59	1.52	.39
NOX CONCENTRATION PPM	32.4	52.1	158.7	33.8
HC MASS GRAMS	.69	1.02	.49	.05
CO MASS GRAMS	23.82	24.39	21.94	19.11
CO2 MASS GRAMS	2002.9	2956.3	7739.9	1945.8
NOX MASS GRAMS	16.70	27.22	84.27	17.54
FUEL KG (LB)	.642 (1.41)	.942 (2.08)	2.443 (5.39)	.621 (1.37)
KW HR (HP HR)	2.28 (3.06)	3.54 (4.75)	10.89 (14.61)	2.33 (3.12)
BSHC G/KW HR (G/HP HR)	.30 (.22)	.29 (.22)	.05 (.03)	.02 (.02)
BSCO G/KW HR (G/HP HR)	10.44 (7.78)	6.89 (5.14)	2.01 (1.50)	8.22 (6.13)
BSCO2 G/KW HR (G/HP HR)	877.77 (654.55)	834.62 (622.37)	710.43 (529.76)	836.35 (623.67)
BSNOX G/KW HR (G/HP HR)	7.32 (5.46)	7.68 (5.73)	7.73 (5.77)	7.54 (5.62)
BSFC KG/KW HR (LB/HP HR)	.281 (.462)	.266 (.437)	.224 (.369)	.267 (.439)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	19.05 (25.54)
BSHC G/KW HR (G/HP HR)	.12 (.09)
BSCO G/KW HR (G/HP HR)	4.69 (3.50)
BSCO2 G/KW HR (G/HP HR)	769. (573.)
BSNOX G/KW HR (G/HP HR)	7.65 (5.71)
BSFC KG/KW HR (LB/HP HR)	.244 (.401)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	5.11
	G/KWHR(G/HPHR)	.27 (.20)
	G/KG FUEL (G/LB FUEL)	1.10 (.50)
	FILTER EFF.	95.8

TABLE ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.JMBLH RUN2
DATE 7/11/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 742.70 MM HG(29.24 IN HG)
DRY BULB TEMP. 21.7 DEG C(71.0 DEG F)

RELATIVE HUMIDITY , ENGINE-68. PCT , CVS-62. PCT
ABSOLUTE HUMIDITY 11.2 GM/KG(78.6 GRAINS/LB)

NOX HUMIDITY C.F. 1.0000

BAG RESULTS	1 NYNF	2 LANF	3 LAF	4 NYNF
BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.0	300.0	305.1	297.9
TOTAL FLOW STD. CU. METRES(SCF)	269.0 (9500.)	272.6 (9627.)	277.2 (9790.)	270.7 (9561.)
HC SAMPLE METER/RANGE/PPM	14.8/22/ 15.	17.7/22/ 18.	12.3/22/ 12.	10.5/22/ 11.
HC BCKGRD METER/RANGE/PPM	12.5/ 2/ 13.	12.0/ 2/ 12.	10.5/ 2/ 11.	10.2/ 2/ 10.
CO SAMPLE METER/RANGE/PPM	83.6/13/ 83.	81.8/13/ 81.	76.3/13/ 75.	66.0/13/ 64.
CO BCKGRD METER/RANGE/PPM	1.1/13/ 1.	1.4/13/ 1.	1.3/13/ 1.	1.3/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	95.6/12/ .44	72.7/11/ .64	85.5/ 3/ 1.58	96.6/12/ .44
CO2 BCKGRD METER/RANGE/PCT	12.5/12/ .04	8.5/11/ .05	3.6/ 3/ .06	14.0/12/ .05
NOX SAMPLE METER/RANGE/PPM	32.4/ 2/ 32.	54.4/ 2/ 54.	56.4/ 3/ 169.	35.8/ 2/ 36.
NOX BCKGRD METER/RANGE/PPM	.4/ 2/ 0.	.2/ 2/ 0.	.1/ 3/ 0.	.4/ 2/ 0.
DILUTION FACTOR	29.97	20.66	8.41	29.70
HC CONCENTRATION PPM	3.	6.	3.	1.
CO CONCENTRATION PPM	80.	77.	70.	61.
CO2 CONCENTRATION PCT	.40	.59	1.54	.40
NOX CONCENTRATION PPM	32.0	54.2	168.9	35.4
HC MASS GRAMS	.43	.99	.49	.11
CO MASS GRAMS	25.03	24.56	22.67	19.20
CO2 MASS GRAMS	1952.6	2955.7	7794.4	1971.4
NOX MASS GRAMS	16.47	28.27	89.58	18.34
FUEL KG (LB)	.626 (1.38)	.942 (2.08)	2.460 (5.42)	.629 (1.39)
KW HR (HP HR)	2.27 (3.05)	3.52 (4.72)	10.87 (14.58)	2.31 (3.10)
BSHC G/KW HR (G/HP HR)	.19 (.14)	.28 (.21)	.05 (.03)	.05 (.03)
BSCO G/KW HR (G/HP HR)	11.00 (8.21)	6.98 (5.20)	2.09 (1.56)	8.30 (6.19)
BSCO2 G/KW HR (G/HP HR)	858.54 (640.21)	839.75 (626.20)	716.90 (534.59)	852.79 (635.92)
BSNOX G/KW HR (G/HP HR)	7.24 (5.40)	8.03 (5.99)	8.24 (6.14)	7.93 (5.92)
BSFC KG/KW HR (LB/HP HR)	.275 (.453)	.268 (.440)	.226 (.372)	.272 (.447)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	18.98 (25.45)
BSHC G/KW HR (G/HP HR)	.11 (.08)
BSCO G/KW HR (G/HP HR)	4.82 (3.59)
BSCO2 G/KW HR (G/HP HR)	773. (577.)
BSNOX G/KW HR (G/HP HR)	8.04 (6.00)
BSFC KG/KW HR (LB/HP HR)	.245 (.403)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	4.94
	G/KWHR(G/HPHR)	.26 (.19)
	G/KG FUEL (G/LB FUEL)	1.06 (.48)
	FILTER EFF.	95.5

T' LE ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.JMLTH RUN1
DATE 7/11/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 740.66 MM HG(29.16 IN HG)
DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)

RELATIVE HUMIDITY , ENGINE-46. PCT , CVS-50. PCT
ABSOLUTE HUMIDITY 9.7 GM/KG(67.7 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

	1	2	3	4
BAG NUMBER				
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.1	300.0	305.1	298.0
TOTAL FLOW STD. CU. METRES(SCF)	268.7 (9490.)	272.2 (9616.)	276.9 (9782.)	270.4 (9549.)
HC SAMPLE METER/RANGE/PPM	9.7/22/ 10.	12.8/22/ 13.	6.6/22/ 7.	5.8/22/ 6.
HC BCKGRD METER/RANGE/PPM	8.0/ 2/ 8.	9.0/ 2/ 9.	6.8/ 2/ 7.	5.8/ 2/ 6.
CO SAMPLE METER/RANGE/PPM	77.2/13/ 76.	83.3/13/ 83.	83.0/13/ 83.	69.4/13/ 67.
CO BCKGRD METER/RANGE/PPM	.3/13/ 0.	1.0/13/ 1.	1.2/13/ 1.	1.0/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	98.4/12/ .46	71.5/11/ .62	84.2/ 3/ 1.56	94.3/12/ .43
CO2 BCKGRD METER/RANGE/PCT	11.8/12/ .04	7.0/11/ .04	2.6/ 3/ .04	12.3/12/ .04
NOX SAMPLE METER/RANGE/PPM	35.2/ 2/ 35.	53.9/ 2/ 54.	56.0/ 3/ 168.	34.9/ 2/ 35.
NOX BCKGRD METER/RANGE/PPM	.4/ 2/ 0.	.3/ 2/ 0.	.1/ 3/ 0.	.3/ 2/ 0.
DILUTION FACTOR	28.88	21.16	8.56	30.70
HC CONCENTRATION PPM	2.	4.	1.	0.
CO CONCENTRATION PPM	74.	80.	78.	65.
CO2 CONCENTRATION PCT	.42	.59	1.52	.39
NOX CONCENTRATION PPM	34.8	53.6	167.7	34.6
HC MASS GRAMS	.31	.66	.10	.02
CO MASS GRAMS	23.12	25.27	25.09	20.46
CO2 MASS GRAMS	2051.9	2919.3	7718.8	1925.3
NOX MASS GRAMS	17.89	27.92	88.86	17.90
FUEL KG (LB)	.656 (1.45)	.930 (2.05)	2.437 (5.37)	.615 (1.36)
KW HR (HP HR)	2.29 (3.07)	3.53 (4.74)	10.86 (14.57)	2.29 (3.07)
BSHC G/KW HR (G/HP HR)	.14 (.10)	.19 (.14)	.01 (.01)	.01 (.01)
BSCO G/KW HR (G/HP HR)	10.10 (7.53)	7.15 (5.33)	2.31 (1.72)	8.94 (6.66)
BSCO2 G/KW HR (G/HP HR)	896.30 (668.37)	825.91 (615.88)	710.44 (529.77)	841.00 (627.13)
BSNOX G/KW HR (G/HP HR)	7.82 (5.83)	7.90 (5.89)	8.18 (6.10)	7.82 (5.83)
BSFC KG/KW HR (LB/HP HR)	.287 (.471)	.263 (.433)	.224 (.369)	.269 (.442)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	18.98 (25.45)
BSHC G/KW HR (G/HP HR)	.06 (.04)
BSCO G/KW HR (G/HP HR)	4.95 (3.69)
BSCO2 G/KW HR (G/HP HR)	770. (574.)
BSNOX G/KW HR (G/HP HR)	8.04 (6.00)
BSFC KG/KW HR (LB/HP HR)	.244 (.402)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	5.54
	G/KWHR(G/HPHR)	.29 (.22)
	G/KG FUEL (G/LB FUEL)	1.19 (.54)
	FILTER EFF.	96.0

TABLE

ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.JMLTH RUN4
DATE 7/12/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 738.63 MM HG(29.08 IN HG)
DRY BULB TEMP. 21.7 DEG C(71.0 DEG F)

RELATIVE HUMIDITY , ENGINE-56. PCT , CVS-59. PCT
ABSOLUTE HUMIDITY 9.3 GM/KG(65.3 GRAINS/LB)

NOX HUMIDITY C.F. 1.0000

BAG RESULTS	1	2	3	4
BAG NUMBER	NYNF	LANF	LAF	NYNF
DESCRIPTION				
TIME SECONDS	296.0	300.1	305.1	297.9
TOTAL FLOW STD. CU. METRES(SCF)	267.3 (9442.)	271.0 (9571.)	275.6 (9733.)	269.0 (9502.)
HC SAMPLE METER/RANGE/PPM	12.4/22/ 12.	15.9/22/ 16.	11.4/22/ 11.	9.5/22/ 10.
HC BCKGRD METER/RANGE/PPM	9.8/ 2/ 10.	10.8/ 2/ 11.	11.0/ 2/ 11.	9.5/ 2/ 10.
CO SAMPLE METER/RANGE/PPM	86.2/13/ 86.	90.2/13/ 91.	91.2/13/ 92.	73.4/13/ 72.
CO BCKGRD METER/RANGE/PPM	.3/13/ 0.	.5/13/ 0.	.9/13/ 1.	1.3/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	95.3/12/ .44	71.9/11/ .63	84.9/ 3/ 1.57	95.1/12/ .43
CO2 BCKGRD METER/RANGE/PCT	11.5/12/ .04	6.7/11/ .04	2.6/ 3/ .04	11.6/12/ .04
NOX SAMPLE METER/RANGE/PPM	32.9/ 2/ 33.	54.7/ 2/ 55.	57.3/ 3/ 172.	35.3/ 2/ 35.
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ 0.	.4/ 2/ 0.	.1/ 3/ 0.	.3/ 2/ 0.
DILUTION FACTOR	30.10	20.96	8.47	30.30
HC CONCENTRATION PPM	3.	6.	2.	0.
CO CONCENTRATION PPM	84.	87.	87.	69.
CO2 CONCENTRATION PCT	.40	.59	1.54	.40
NOX CONCENTRATION PPM	32.6	54.3	171.6	35.0
HC MASS GRAMS	.44	.87	.27	.05
CO MASS GRAMS	26.01	27.61	27.81	21.54
CO2 MASS GRAMS	1948.3	2939.4	7754.1	1952.6
NOX MASS GRAMS	16.68	28.16	90.47	18.02
FUEL KG (LB)	.625 (1.38)	.938 (2.07)	2.450 (5.40)	.624 (1.38)
KW HR (HP HR)	2.22 (2.98)	3.48 (4.67)	10.83 (14.52)	2.27 (3.05)
BSHC G/KW HR (G/HP HR)	.20 (.15)	.25 (.19)	.02 (.02)	.02 (.02)
BSCO G/KW HR (G/HP HR)	11.70 (8.73)	7.93 (5.91)	2.57 (1.92)	9.47 (7.06)
BSCO2 G/KW HR (G/HP HR)	876.76 (653.80)	844.06 (629.41)	716.14 (534.03)	858.52 (640.20)
BSNOX G/KW HR (G/HP HR)	7.50 (5.60)	8.09 (6.03)	8.36 (6.23)	7.92 (5.91)
BSFC KG/KW HR (LB/HP HR)	.281 (.463)	.269 (.443)	.226 (.372)	.274 (.451)

TOTAL TEST RESULTS 4 BAGS

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

TOTAL KW HR (HP HR)	18.81 (25.22)
BSHC G/KW HR (G/HP HR)	.09 (.06)
BSCO G/KW HR (G/HP HR)	5.48 (4.08)
BSCO2 G/KW HR (G/HP HR)	776. (579.)
BSNOX G/KW HR (G/HP HR)	8.15 (6.08)
BSFC KG/KW HR (LB/HP HR)	.247 (.405)

90MM PARTICULATE RATES

GRAMS/TEST	5.99
G/KWHR(G/HPHR)	.32 (.24)
G/KG FUEL (G/LB FUEL)	1.29 (.59)
FILTER EFF.	100.0

TABLE ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.FBL RUN1
DATE 7/13/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 742.44 MM HG(29.23 IN HG)
DRY BULB TEMP. 22.2 DEG C(72.0 DEG F)

RELATIVE HUMIDITY , ENGINE-65. PCT , CVS-56. PCT
ABSOLUTE HUMIDITY 11.2 GM/KG(78.3 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS	1 NYNF	2 LANF	3 LAF	4 NYNF
BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.0	300.1	305.0	297.9
TOTAL FLOW STD. CU. METRES(SCF)	268.6 (9486.)	272.2 (9615.)	276.7 (9773.)	270.2 (9544.)
HC SAMPLE METER/RANGE/PPM	26.6/22/ 27.	29.6/22/ 30.	26.0/22/ 26.	30.3/22/ 30.
HC BCKGRD METER/RANGE/PPM	8.3/ 2/ 8.	9.0/ 2/ 9.	8.8/ 2/ 9.	8.8/ 2/ 9.
CO SAMPLE METER/RANGE/PPM	82.1/13/ 82.	76.8/13/ 76.	66.6/13/ 64.	71.0/13/ 69.
CO BCKGRD METER/RANGE/PPM	.2/13/ 0.	.9/13/ 1.	1.0/13/ 1.	.9/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	95.7/12/ .44	71.8/11/ .63	84.4/ 3/ 1.56	93.7/12/ .43
CO2 BCKGRD METER/RANGE/PCT	11.8/12/ .04	7.0/11/ .04	2.8/ 3/ .04	11.6/12/ .04
NOX SAMPLE METER/RANGE/PPM	34.4/ 2/ 34.	57.4/ 2/ 57.	61.6/ 3/ 185.	36.9/ 2/ 37.
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ 0.	.3/ 2/ 0.	.1/ 3/ 0.	.3/ 2/ 0.
DILUTION FACTOR	29.86	21.00	8.54	30.79
HC CONCENTRATION PPM	19.	21.	18.	22.
CO CONCENTRATION PPM	79.	73.	61.	67.
CO2 CONCENTRATION PCT	.40	.59	1.52	.39
NOX CONCENTRATION PPM	34.1	57.1	184.5	36.6
HC MASS GRAMS	2.88	3.30	2.90	3.40
CO MASS GRAMS	24.77	23.00	19.52	20.97
CO2 MASS GRAMS	1964.8	2938.0	7719.3	1917.5
NOX MASS GRAMS	17.52	29.74	97.68	18.92
FUEL KG (LB)	.632 (1.39)	.938 (2.07)	2.438 (5.37)	.616 (1.36)
KW HR (HP HR)	2.13 (2.85)	3.49 (4.68)	10.92 (14.65)	2.23 (2.99)
BSHC G/KW HR (G/HP HR)	1.35 (1.01)	.95 (.71)	.27 (.20)	1.52 (1.14)
BSCO G/KW HR (G/HP HR)	11.65 (8.69)	6.59 (4.91)	1.79 (1.33)	9.40 (7.01)
BSCO2 G/KW HR (G/HP HR)	924.52 (689.42)	841.86 (627.77)	706.60 (526.91)	859.99 (641.30)
BSNOX G/KW HR (G/HP HR)	8.25 (6.15)	8.52 (6.36)	8.94 (6.67)	8.49 (6.33)
BSFC KG/KW HR (LB/HP HR)	.298 (.489)	.269 (.442)	.223 (.367)	.276 (.454)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	18.77 (25.17)
BSHC G/KW HR (G/HP HR)	.67 (.50)
BSCO G/KW HR (G/HP HR)	4.70 (3.51)
BSCO2 G/KW HR (G/HP HR)	775. (578.)
BSNOX G/KW HR (G/HP HR)	8.73 (6.51)
BSFC KG/KW HR (LB/HP HR)	.246 (.405)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	
GRAMS/TEST	10.12
G/KWHR(G/HPHR)	.54 (.40)
G/KG FUEL (G/LB FUEL)	2.19 (.99)
FILTER EFF.	97.1

TABLE ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.FBL RUN2
DATE 7/13/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 741.93 MM HG(29.21 IN HG)
DRY BULB TEMP. 22.2 DEG C(72.0 DEG F)

RELATIVE HUMIDITY , ENGINE-65. PCT , CVS-57. PCT
ABSOLUTE HUMIDITY 11.2 GM/KG(78.3 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS	1	2	3	4
BAG NUMBER	NYNF	LANF	LAF	NYNF
DESCRIPTION				
TIME SECONDS	296.0	300.0	305.0	297.8
TOTAL FLOW STD. CU. METRES(SCF)	267.6 (9453.)	271.2 (9580.)	275.8 (9743.)	269.3 (9513.)
HC SAMPLE METER/RANGE/PPM	25.7/22/ 26.	29.9/22/ 30.	26.9/22/ 27.	30.4/22/ 30.
HC BCKGRD METER/RANGE/PPM	9.0/ 2/ 9.	9.0/ 2/ 9.	7.8/ 2/ 8.	7.8/ 2/ 8.
CO SAMPLE METER/RANGE/PPM	75.9/13/ 75.	73.5/13/ 72.	65.5/13/ 63.	69.0/13/ 67.
CO BCKGRD METER/RANGE/PPM	.2/13/ 0.	.2/13/ 0.	.3/13/ 0.	.6/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	94.5/12/ .43	71.8/11/ .63	84.1/ 3/ 1.55	93.6/12/ .42
CO2 BCKGRD METER/RANGE/PCT	11.6/12/ .04	6.7/11/ .04	2.8/ 3/ .04	11.6/12/ .04
NOX SAMPLE METER/RANGE/PPM	35.3/ 2/ 35.	59.3/ 2/ 59.	61.2/ 3/ 184.	37.1/ 2/ 37.
NOX BCKGRD METER/RANGE/PPM	.2/ 2/ 0.	.3/ 2/ 0.	.1/ 3/ 0.	.3/ 2/ 0.
DILUTION FACTOR	30.43	21.02	8.57	30.84
HC CONCENTRATION PPM	17.	21.	20.	23.
CO CONCENTRATION PPM	72.	70.	60.	65.
CO2 CONCENTRATION PCT	.39	.59	1.52	.39
NOX CONCENTRATION PPM	35.1	59.0	183.3	36.8
HC MASS GRAMS	2.63	3.33	3.19	3.55
CO MASS GRAMS	22.58	21.98	19.27	20.31
CO2 MASS GRAMS	1923.9	2935.9	7663.6	1908.1
NOX MASS GRAMS	17.97	30.62	96.74	18.97
FUEL KG (LB)	.618 (1.36)	.937 (2.06)	2.420 (5.34)	.613 (1.35)
KW HR (HP HR)	2.18 (2.93)	3.50 (4.70)	10.89 (14.61)	2.24 (3.00)
BSHC G/KW HR (G/HP HR)	1.20 (.90)	.95 (.71)	.29 (.22)	1.59 (1.18)
BSCO G/KW HR (G/HP HR)	10.33 (7.71)	6.27 (4.68)	1.77 (1.32)	9.08 (6.77)
BSCO2 G/KW HR (G/HP HR)	880.55 (656.63)	837.70 (624.67)	703.42 (524.54)	852.95 (636.04)
BSNOX G/KW HR (G/HP HR)	8.23 (6.13)	8.74 (6.51)	8.88 (6.62)	8.48 (6.32)
BSFC KG/KW HR (LB/HP HR)	.283 (.465)	.267 (.439)	.222 (.365)	.274 (.450)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	18.82 (25.24)
BSHC G/KW HR (G/HP HR)	.67 (.50)
BSCO G/KW HR (G/HP HR)	4.47 (3.33)
BSCO2 G/KW HR (G/HP HR)	767. (572.)
BSNOX G/KW HR (G/HP HR)	8.73 (6.51)
BSFC KG/KW HR (LB/HP HR)	.244 (.401)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	9.59
	G/KWHR(G/HPHR)	.51 (.38)
	G/KG FUEL (G/LB FUEL)	2.09 (.95)
	FILTER EFF.	97.0

TABLE ENGINE EMISSION RESULTS
C-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.BLWOC RUN1
DATE 6/11/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 743.20 MM HG(29.26 IN HG)
DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)

RELATIVE HUMIDITY , ENGINE-47. PCT , CVS-65. PCT
ABSOLUTE HUMIDITY 9.1 GM/KG(63.8 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

	1	2	3	4
BAG NUMBER				
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.0	300.0	305.0	297.9
TOTAL FLOW STD. CU. METRES(SCF)	269.7 (9526.)	273.3 (9654.)	277.9 (9816.)	271.4 (9584.)
HC SAMPLE METER/RANGE/PPM	20.2/23/ 101.	9.3/23/ 47.	7.3/23/ 37.	7.4/23/ 37.
HC BCKGRD METER/RANGE/PPM	14.8/ 2/ 15.	14.7/ 2/ 15.	14.9/ 2/ 15.	14.0/ 2/ 14.
CO SAMPLE METER/RANGE/PPM	84.3/13/ 84.	48.9/12/ 103.	68.3/12/ 154.	63.8/13/ 61.
CO BCKGRD METER/RANGE/PPM	.1/13/ 0.	.1/12/ 0.	.3/12/ 1.	.3/13/ 0.
CO2 SAMPLE METER/RANGE/PCT	93.6/12/ .42	71.4/11/ .62	84.6/ 3/ 1.57	89.1/12/ .40
CO2 BCKGRD METER/RANGE/PCT	12.6/12/ .04	7.4/11/ .04	2.6/ 3/ .04	12.2/12/ .04
NOX SAMPLE METER/RANGE/PPM	82.2/ 1/ 24.	38.4/ 2/ 38.	49.3/ 3/ 148.	88.7/ 1/ 26.
NOX BCKGRD METER/RANGE/PPM	.5/ 1/ 0.	.1/ 2/ 0.	.1/ 3/ 0.	.7/ 1/ 0.
DILUTION FACTOR	30.24	21.03	8.46	32.93
HC CONCENTRATION PPM	87.	33.	23.	23.
CO CONCENTRATION PPM	81.	100.	146.	59.
CO2 CONCENTRATION PCT	.38	.58	1.53	.36
NOX CONCENTRATION PPM	24.3	38.3	147.6	26.2
HC MASS GRAMS	13.48	5.13	3.76	3.66
CO MASS GRAMS	25.59	31.71	47.25	18.79
CO2 MASS GRAMS	1893.8	2913.0	7788.2	1774.8
NOX MASS GRAMS	12.54	20.03	78.49	13.59
FUEL KG (LB)	.621 (1.37)	.936 (2.06)	2.474 (5.45)	.570 (1.26)
KW HR (HP HR)	1.60 (2.15)	3.12 (4.19)	11.52 (15.45)	2.04 (2.73)
BSHC G/KW HR (G/HP HR)	8.41 (6.27)	1.64 (1.23)	.33 (.24)	1.80 (1.34)
BSCO G/KW HR (G/HP HR)	15.96 (11.90)	10.15 (7.57)	4.10 (3.06)	9.23 (6.88)
BSCO2 G/KW HR (G/HP HR)	1181.22 (880.84)	932.31 (695.22)	676.00 (504.09)	871.81 (650.11)
BSNOX G/KW HR (G/HP HR)	7.82 (5.83)	6.41 (4.78)	6.81 (5.08)	6.68 (4.98)
BSFC KG/KW HR (LB/HP HR)	.387 (.637)	.300 (.492)	.215 (.353)	.280 (.461)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	18.28 (24.52)
BSHC G/KW HR (G/HP HR)	1.42 (1.06)
BSCO G/KW HR (G/HP HR)	6.75 (5.03)
BSCO2 G/KW HR (G/HP HR)	786. (586.)
BSNOX G/KW HR (G/HP HR)	6.82 (5.08)
BSFC KG/KW HR (LB/HP HR)	.252 (.414)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES GRAMS/TEST	19.33
G/KWHR(G/HPHR)	1.06 (.79)
G/KG FUEL (G/LB FUEL)	4.20 (1.91)
FILTER EFF.	96.6

TITLE ENGINE EMISSION RESULTS
C-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.BLWOC RUN2
DATE 6/18/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 743.20 MM HG(29.26 IN HG)
DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)

RELATIVE HUMIDITY , ENGINE-50. PCT , CVS-59. PCT
ABSOLUTE HUMIDITY 10.1 GM/KG(71.0 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

	1	2	3	4
BAG NUMBER				
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.7	300.1	305.2	298.1
TOTAL FLOW STD. CU. METRES(SCF)	269.9 (9533.)	273.5 (9662.)	278.2 (9825.)	271.7 (9595.)
HC SAMPLE METER/RANGE/PPM	16.6/23/ 83.	8.7/23/ 43.	6.8/23/ 34.	6.8/23/ 34.
HC BCKGRD METER/RANGE/PPM	9.5/ 2/ 10.	10.0/ 2/ 10.	10.8/ 2/ 11.	11.0/ 2/ 11.
CO SAMPLE METER/RANGE/PPM	77.9/13/ 77.	94.4/13/ 96.	60.9/12/ 134.	50.1/13/ 47.
CO BCKGRD METER/RANGE/PPM	2.4/13/ 2.	1.5/13/ 1.	.7/12/ 1.	1.2/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	55.5/11/ .44	69.5/11/ .60	82.2/ 3/ 1.52	85.4/12/ .38
CO2 BCKGRD METER/RANGE/PCT	7.3/11/ .04	7.2/11/ .04	3.0/ 3/ .05	12.3/12/ .04
NOX SAMPLE METER/RANGE/PPM	85.3/ 1/ 25.	37.4/ 2/ 37.	45.5/ 3/ 137.	81.7/ 1/ 24.
NOX BCKGRD METER/RANGE/PPM	1.1/ 1/ 0.	.2/ 2/ 0.	.1/ 3/ 0.	1.3/ 1/ 0.
DILUTION FACTOR	29.46	21.88	8.75	34.94
HC CONCENTRATION PPM	74.	34.	24.	23.
CO CONCENTRATION PPM	73.	91.	126.	45.
CO2 CONCENTRATION PCT	.40	.56	1.47	.33
NOX CONCENTRATION PPM	25.1	37.2	136.2	23.9
HC MASS GRAMS	11.45	5.35	3.92	3.66
CO MASS GRAMS	22.84	29.12	40.94	14.24
CO2 MASS GRAMS	1969.8	2802.1	7512.5	1666.2
NOX MASS GRAMS	12.94	19.47	72.49	12.44
FUEL KG (LB)	.642 (1.41)	.900 (1.98)	2.384 (5.26)	.534 (1.18)
KW HR (HP HR)	1.56 (2.09)	2.96 (3.97)	10.89 (14.60)	1.92 (2.58)
BSHC G/KW HR (G/HP HR)	7.35 (5.48)	1.81 (1.35)	.36 (.27)	1.90 (1.42)
BSCO G/KW HR (G/HP HR)	14.65 (10.93)	9.84 (7.33)	3.76 (2.80)	7.40 (5.52)
BSCO2 G/KW HR (G/HP HR)	1263.92 (942.51)	946.53 (705.83)	690.03 (514.56)	866.05 (645.82)
BSNOX G/KW HR (G/HP HR)	8.30 (6.19)	6.58 (4.90)	6.66 (4.97)	6.46 (4.82)
BSFC KG/KW HR (LB/HP HR)	.412 (.677)	.304 (.500)	.219 (.360)	.278 (.456)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	17.33 (23.24)
BSHC G/KW HR (G/HP HR)	1.41 (1.05)
BSCO G/KW HR (G/HP HR)	6.18 (4.61)
BSCO2 G/KW HR (G/HP HR)	805. (600.)
BSNOX G/KW HR (G/HP HR)	6.77 (5.05)
BSFC KG/KW HR (LB/HP HR)	.257 (.423)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES

GRAMS/TEST	14.98
G/KWHR(G/HPHR)	.86 (.64)
G/KG FUEL (G/LB FUEL)	3.36 (1.52)
FILTER EFF.	97.0

TABLE ENGINE EMISSION RESULTS
C-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.BLWTC RUN1
DATE 6/ 8/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 739.65 MM HG(29.12 IN HG)
DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)

RELATIVE HUMIDITY , ENGINE-55. PCT , CVS-59. PCT
ABSOLUTE HUMIDITY 10.8 GM/KG(75.3 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

	1	2	3	4
BAG NUMBER				
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.9	305.0	298.0
TOTAL FLOW STD. CU. METRES(SCF)	269.1 (9504.)	272.6 (9630.)	277.2 (9791.)	270.8 (9565.)
HC SAMPLE METER/RANGE/PPM	80.8/22/ 81.	49.0/22/ 49.	23.8/22/ 24.	26.5/22/ 26.
HC BCKGRD METER/RANGE/PPM	11.5/ 2/ 12.	11.3/ 2/ 11.	9.7/ 2/ 10.	9.5/ 2/ 10.
CO SAMPLE METER/RANGE/PPM	81.6/13/ 81.	59.7/13/ 57.	89.0/12/ 218.	36.2/13/ 34.
CO BCKGRD METER/RANGE/PPM	.6/13/ 1.	.7/13/ 1.	.4/12/ 1.	.8/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	91.1/12/ .41	62.9/11/ .52	77.4/ 3/ 1.42	79.4/12/ .34
CO2 BCKGRD METER/RANGE/PCT	11.3/12/ .04	6.9/11/ .04	2.9/ 3/ .04	12.0/12/ .04
NOX SAMPLE METER/RANGE/PPM	83.5/ 1/ 25.	95.0/ 1/ 28.	33.6/ 3/ 101.	69.8/ 1/ 21.
NOX BCKGRD METER/RANGE/PPM	.5/ 1/ 0.	.5/ 1/ 0.	.1/ 3/ 0.	.8/ 1/ 0.
DILUTION FACTOR	31.50	25.24	9.31	38.57
HC CONCENTRATION PPM	70.	38.	15.	17.
CO CONCENTRATION PPM	78.	55.	207.	32.
CO2 CONCENTRATION PCT	.37	.48	1.38	.30
NOX CONCENTRATION PPM	24.7	28.1	100.5	20.5
HC MASS GRAMS	10.82	6.00	2.42	2.69
CO MASS GRAMS	24.52	17.43	66.89	10.08
CO2 MASS GRAMS	1835.1	2409.0	6987.2	1497.2
NOX MASS GRAMS	12.71	14.67	53.31	10.64
FUEL KG (LB)	.599 (1.32)	.771 (1.70)	2.230 (4.92)	.478 (1.05)
KW HR (HP HR)	1.48 (1.98)	2.21 (2.97)	8.77 (11.76)	1.59 (2.13)
BSHC G/KW HR (G/HP HR)	7.33 (5.46)	2.71 (2.02)	.28 (.21)	1.69 (1.26)
BSCO G/KW HR (G/HP HR)	16.61 (12.39)	7.87 (5.87)	7.63 (5.69)	6.35 (4.73)
BSCO2 G/KW HR (G/HP HR)	1242.88 (926.81)	1087.73 (811.12)	796.76 (594.15)	942.62 (702.91)
BSNOX G/KW HR (G/HP HR)	8.61 (6.42)	6.62 (4.94)	6.08 (4.53)	6.70 (4.99)
BSFC KG/KW HR (LB/HP HR)	.406 (.667)	.348 (.573)	.254 (.418)	.301 (.495)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	14.05 (18.84)
BSHC G/KW HR (G/HP HR)	1.56 (1.16)
BSCO G/KW HR (G/HP HR)	8.47 (6.31)
BSCO2 G/KW HR (G/HP HR)	906. (676.)
BSNOX G/KW HR (G/HP HR)	6.50 (4.85)
BSFC KG/KW HR (LB/HP HR)	.290 (.477)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	3.35
	G/KWHR(G/HPHR)	.24 (.18)
	G/KG FUEL (G/LB FUEL)	.82 (.37)
	FILTER EFF.	84.5

TABLE ENGINE EMISSION RESULTS
C-TRANS.

PROJECT NO. 03-7338-003

TEST NO.BLDT RUN1
DATE 6/20/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

RELATIVE HUMIDITY , ENGINE-56. PCT , CVS-62. PCT
ABSOLUTE HUMIDITY 10.6 GM/KG(74.4 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

BAROMETER 743.71 MM HG(29.28 IN HG)
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)

BAG RESULTS	1	2	3	4
BAG NUMBER	NYNF	LANF	LAF	NYNF
DESCRIPTION				
TIME SECONDS	296.0	300.0	305.1	298.0
TOTAL FLOW STD. CU. METRES(SCF)	271.2 (9578.)	274.9 (9709.)	279.5 (9871.)	272.9 (9640.)
HC SAMPLE METER/RANGE/PPM	16.2/23/ 81.	9.1/23/ 46.	6.6/23/ 33.	6.7/23/ 34.
HC BCKGRD METER/RANGE/PPM	10.8/ 2/ 11.	10.5/ 2/ 11.	10.0/ 2/ 10.	10.0/ 2/ 10.
CO SAMPLE METER/RANGE/PPM	68.3/13/ 66.	82.9/13/ 82.	86.9/12/ 211.	43.9/13/ 41.
CO BCKGRD METER/RANGE/PPM	.1/13/ 0.	.2/13/ 0.	.3/12/ 1.	.1/13/ 0.
CO2 SAMPLE METER/RANGE/PCT	87.8/12/ .39	66.9/11/ .57	83.3/ 3/ 1.54	82.5/12/ .36
CO2 BCKGRD METER/RANGE/PCT	12.7/12/ .04	7.6/11/ .04	3.0/ 3/ .05	12.4/12/ .04
NOX SAMPLE METER/RANGE/PPM	74.7/ 1/ 22.	32.4/ 2/ 32.	43.8/ 3/ 131.	77.3/ 1/ 23.
NOX BCKGRD METER/RANGE/PPM	.1/ 1/ 0.	.1/ 2/ 0.	.1/ 3/ 0.	.7/ 1/ 0.
DILUTION FACTOR	33.16	23.11	8.58	36.59
HC CONCENTRATION PPM	71.	36.	24.	24.
CO CONCENTRATION PPM	64.	80.	200.	40.
CO2 CONCENTRATION PCT	.35	.53	1.50	.32
NOX CONCENTRATION PPM	22.2	32.3	131.1	22.8
HC MASS GRAMS	11.07	5.64	3.86	3.76
CO MASS GRAMS	20.34	25.51	65.12	12.67
CO2 MASS GRAMS	1726.6	2644.6	7665.5	1589.0
NOX MASS GRAMS	11.51	16.99	70.11	11.90
FUEL KG (LB)	.564 (1.24)	.849 (1.87)	2.444 (5.39)	.509 (1.12)
KW HR (HP HR)	1.60 (2.14)	2.74 (3.68)	10.78 (14.45)	1.94 (2.60)
BSHC G/KW HR (G/HP HR)	6.94 (5.17)	2.05 (1.53)	.36 (.27)	1.94 (1.44)
BSCO G/KW HR (G/HP HR)	12.74 (9.50)	9.30 (6.93)	6.04 (4.51)	6.54 (4.87)
BSCO2 G/KW HR (G/HP HR)	1081.98 (806.83)	963.73 (718.65)	711.39 (530.49)	819.56 (611.14)
BSNOX G/KW HR (G/HP HR)	7.21 (5.38)	6.19 (4.62)	6.51 (4.85)	6.14 (4.58)
BSFC KG/KW HR (LB/HP HR)	.353 (.581)	.309 (.509)	.227 (.373)	.263 (.432)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	17.05 (22.87)
BSHC G/KW HR (G/HP HR)	1.43 (1.06)
BSCO G/KW HR (G/HP HR)	7.25 (5.41)
BSCO2 G/KW HR (G/HP HR)	799. (596.)
BSNOX G/KW HR (G/HP HR)	6.48 (4.83)
BSFC KG/KW HR (LB/HP HR)	.256 (.421)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	
GRAMS/TEST	16.69
G/KWHR(G/HPHR)	.98 (.73)
G/KG FUEL (G/LB FUEL)	3.82 (1.73)
FILTER EFF.	96.7

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ENGINE EMISSION RESULTS
C-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.RBLC RUN1
DATE 6/22/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 742.70 MM HG(29.24 IN HG)
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)

RELATIVE HUMIDITY , ENGINE-52. PCT , CVS-58. PCT
ABSOLUTE HUMIDITY 9.9 GM/KG(69.1 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

	1	2	3	4
BAG NUMBER				
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.0	300.0	305.0	297.9
TOTAL FLOW STD. CU. METRES(SCF)	269.6 (9522.)	273.2 (9651.)	277.9 (9816.)	271.3 (9582.)
HC SAMPLE METER/RANGE/PPM	16.5/23/ 82.	8.9/23/ 45.	7.3/23/ 37.	7.3/23/ 36.
HC BCKGRD METER/RANGE/PPM	8.5/ 2/ 9.	9.0/ 2/ 9.	9.8/ 2/ 10.	10.0/ 2/ 10.
CO SAMPLE METER/RANGE/PPM	78.0/13/ 77.	83.0/13/ 83.	85.0/13/ 85.	69.7/13/ 68.
CO BCKGRD METER/RANGE/PPM	.7/13/ 1.	1.0/13/ 1.	1.5/13/ 1.	2.4/13/ 2.
CO2 SAMPLE METER/RANGE/PCT	94.6/12/ .43	72.8/11/ .64	85.3/ 3/ 1.58	91.9/12/ .41
CO2 BCKGRD METER/RANGE/PCT	12.2/12/ .04	7.2/11/ .04	3.1/ 3/ .05	13.3/12/ .05
NOX SAMPLE METER/RANGE/PPM	90.2/ 1/ 27.	46.8/ 2/ 47.	51.9/ 3/ 156.	32.1/ 2/ 32.
NOX BCKGRD METER/RANGE/PPM	.9/ 1/ 0.	.2/ 2/ 0.	.1/ 3/ 0.	.8/ 2/ 1.
DILUTION FACTOR	29.99	20.52	8.42	31.56
HC CONCENTRATION PPM	74.	36.	28.	27.
CO CONCENTRATION PPM	74.	79.	79.	64.
CO2 CONCENTRATION PCT	.39	.60	1.54	.37
NOX CONCENTRATION PPM	26.6	46.6	155.4	31.3
HC MASS GRAMS	11.54	5.69	4.48	4.16
CO MASS GRAMS	23.31	25.18	25.72	20.20
CO2 MASS GRAMS	1930.9	3007.3	7828.7	1840.1
NOX MASS GRAMS	13.70	24.36	82.64	16.26
FUEL KG (LB)	.630 (1.39)	.963 (2.12)	2.477 (5.46)	.592 (1.31)
KW HR (HP HR)	1.89 (2.53)	3.36 (4.51)	11.28 (15.13)	2.22 (2.98)
BSHC G/KW HR (G/HP HR)	6.12 (4.56)	1.69 (1.26)	.40 (.30)	1.87 (1.40)
BSCO G/KW HR (G/HP HR)	12.36 (9.21)	7.49 (5.58)	2.28 (1.70)	9.09 (6.78)
BSCO2 G/KW HR (G/HP HR)	1023.46 (763.19)	894.21 (666.81)	693.88 (517.43)	828.08 (617.50)
BSNOX G/KW HR (G/HP HR)	7.26 (5.42)	7.24 (5.40)	7.32 (5.46)	7.32 (5.45)
BSFC KG/KW HR (LB/HP HR)	.334 (.549)	.286 (.471)	.220 (.361)	.267 (.438)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	18.75 (25.15)
BSHC G/KW HR (G/HP HR)	1.38 (1.03)
BSCO G/KW HR (G/HP HR)	5.03 (3.75)
BSCO2 G/KW HR (G/HP HR)	779. (581.)
BSNOX G/KW HR (G/HP HR)	7.30 (5.45)
BSFC KG/KW HR (LB/HP HR)	.249 (.409)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	12.79
	G/KWHR(G/HPHR)	.68 (.51)
	G/KG FUEL (G/LB FUEL)	2.74 (1.24)
	FILTER EFF.	96.0

TABLE ENGINE EMISSION RESULTS
C-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.BLSTC RUN1
DATE 7/ 2/84
TIME 1:55
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 741.17 MM HG(29.18 IN HG)
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)

RELATIVE HUMIDITY , ENGINE-53. PCT , CVS-63. PCT
ABSOLUTE HUMIDITY 10.1 GM/KG(70.6 GRAINS/LB)

NOX HUMIDITY C.F. 1.0000

BAG RESULTS	1	2	3	4
BAG NUMBER				
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.1	300.1	300.5	298.0
TOTAL FLOW STD. CU. METRES(SCF)	268.9 (9497.)	272.4 (9621.)	277.4 (9797.)	270.5 (9555.)
HC SAMPLE METER/RANGE/PPM	81.8/22/ 82.	41.4/22/ 41.	26.0/22/ 26.	28.7/22/ 29.
HC BCKGRD METER/RANGE/PPM	8.0/ 2/ 8.	9.1/ 2/ 9.	9.0/ 2/ 9.	9.0/ 2/ 9.
CO SAMPLE METER/RANGE/PPM	76.2/13/ 75.	62.9/13/ 61.	81.8/12/ 195.	47.6/13/ 45.
CO BCKGRD METER/RANGE/PPM	.6/13/ 1.	.7/13/ 1.	.1/12/ 0.	.1/13/ 0.
CO2 SAMPLE METER/RANGE/PCT	92.1/12/ .42	65.3/11/ .55	82.0/ 3/ 1.51	86.2/12/ .38
CO2 BCKGRD METER/RANGE/PCT	12.1/12/ .04	7.1/11/ .04	3.3/ 3/ .05	11.9/12/ .04
NOX SAMPLE METER/RANGE/PPM	82.8/ 1/ 25.	98.1/ 1/ 29.	43.2/ 3/ 130.	77.9/ 1/ 23.
NOX BCKGRD METER/RANGE/PPM	.4/ 1/ 0.	.3/ 1/ 0.	.1/ 3/ 0.	.8/ 1/ 0.
DILUTION FACTOR	31.09	24.00	8.75	34.59
HC CONCENTRATION PPM	74.	33.	18.	20.
CO CONCENTRATION PPM	72.	58.	185.	43.
CO2 CONCENTRATION PCT	.38	.51	1.47	.34
NOX CONCENTRATION PPM	24.5	29.1	129.3	22.9
HC MASS GRAMS	11.48	5.14	2.88	3.11
CO MASS GRAMS	22.64	18.42	59.73	13.68
CO2 MASS GRAMS	1850.4	2540.2	7449.2	1689.2
NOX MASS GRAMS	12.61	15.16	68.63	11.87
FUEL KG (LB)	.604 (1.33)	.812 (1.79)	2.373 (5.23)	.541 (1.19)
KW HR (HP HR)	1.54 (2.07)	2.41 (3.23)	10.08 (13.52)	1.82 (2.44)
BSHC G/KW HR (G/HP HR)	7.44 (5.55)	2.13 (1.59)	.29 (.21)	1.71 (1.27)
BSCO G/KW HR (G/HP HR)	14.67 (10.94)	7.65 (5.70)	5.92 (4.42)	7.52 (5.61)
BSCO2 G/KW HR (G/HP HR)	1198.78 (893.93)	1054.62 (786.43)	738.87 (550.98)	928.37 (692.29)
BSNOX G/KW HR (G/HP HR)	8.17 (6.09)	6.29 (4.69)	6.81 (5.08)	6.53 (4.87)
BSFC KG/KW HR (LB/HP HR)	.391 (.643)	.337 (.554)	.235 (.387)	.297 (.488)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	15.85 (21.26)
BSHC G/KW HR (G/HP HR)	1.43 (1.06)
BSCO G/KW HR (G/HP HR)	7.22 (5.38)
BSCO2 G/KW HR (G/HP HR)	853. (636.)
BSNOX G/KW HR (G/HP HR)	6.83 (5.09)
BSFC KG/KW HR (LB/HP HR)	.273 (.449)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	3.02
	G/KWHR(G/HPHR)	.19 (.14)
	G/KG FUEL (G/LB FUEL)	.70 (.32)
	FILTER EFF.	82.2

TABLE ENGINE EMISSION RESULTS
C-TRANS.

PROJECT NO. 03-7338-003

ENGINE NO.
ENGINE MODEL 83 CUMMINS NTC-400
ENGINE 0.0 L(0. CID)
CVS NO. 10

TEST NO.JMBLC RUN1
DATE 7/11/84
TIME
DYNO NO. 5

DIESEL EM-597-F
BAG CART NO. 1

BAROMETER 742.70 MM HG(29.24 IN HG)
DRY BULB TEMP. 22.2 DEG C(72.0 DEG F)

RELATIVE HUMIDITY , ENGINE-51. PCT , CVS-62. PCT
ABSOLUTE HUMIDITY 8.7 GM/KG(61.2 GRAINS/LB)

NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.2	300.2	305.2	298.0
TOTAL FLOW STD. CU. METRES(SCF)	269.1 (9506.)	272.6 (9628.)	277.1 (9788.)	270.5 (9554.)
HC SAMPLE METER/RANGE/PPM	11.7/23/ 58.	6.3/23/ 32.	4.1/23/ 21.	2.4/23/ 12.
HC BCKGRD METER/RANGE/PPM	16.2/ 2/ 16.	15.5/ 2/ 16.	14.8/ 2/ 15.	12.0/ 2/ 12.
CO SAMPLE METER/RANGE/PPM	97.0/13/ 99.	85.2/13/ 85.	87.1/13/ 87.	65.0/13/ 63.
CO BCKGRD METER/RANGE/PPM	.6/13/ 1.	.7/13/ 1.	1.0/13/ 1.	1.0/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	60.0/11/ .49	74.0/11/ .86	85.2/ 3/ 1.58	95.6/12/ .44
CO2 BCKGRD METER/RANGE/PCT	12.2/12/ .04	7.1/11/ .04	2.7/ 3/ .04	11.7/12/ .04
NOX SAMPLE METER/RANGE/PPM	33.6/ 2/ 34.	47.1/ 2/ 47.	49.6/ 3/ 149.	33.6/ 2/ 34.
NOX BCKGRD METER/RANGE/PPM	1.4/ 1/ 0.	.3/ 2/ 0.	.1/ 3/ 0.	.4/ 2/ 0.
DILUTION FACTOR	26.63	20.08	8.44	30.13
HC CONCENTRATION PPM	43.	17.	7.	0.
CO CONCENTRATION PPM	95.	82.	82.	60.
CO2 CONCENTRATION PCT	.45	.62	1.54	.40
NOX CONCENTRATION PPM	33.2	46.8	148.5	33.2
HC MASS GRAMS	6.64	2.66	1.20	.04
CO MASS GRAMS	29.84	25.93	26.47	18.94
CO2 MASS GRAMS	2208.1	3080.7	7823.0	1977.5
NOX MASS GRAMS	17.10	24.41	78.74	17.19
FUEL KG (LB)	.715 (1.58)	.983 (2.17)	2.472 (5.45)	.631 (1.39)
KW HR (HP HR)	1.93 (2.59)	3.38 (4.53)	10.92 (14.64)	2.32 (3.11)
BSHC G/KW HR (G/HP HR)	3.44 (2.56)	.79 (.59)	.11 (.08)	.02 (.01)
BSCO G/KW HR (G/HP HR)	15.45 (11.52)	7.67 (5.72)	2.42 (1.81)	8.17 (6.09)
BSCO2 G/KW HR (G/HP HR)	1143.28 (852.54)	911.98 (680.07)	716.59 (534.36)	852.68 (635.84)
BSNOX G/KW HR (G/HP HR)	8.85 (6.60)	7.23 (5.39)	7.21 (5.38)	7.41 (5.53)
BSFC KG/KW HR (LB/HP HR)	.370 (.609)	.291 (.479)	.226 (.372)	.272 (.447)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	18.55 (24.87)
BSHC G/KW HR (G/HP HR)	.57 (.42)
BSCO G/KW HR (G/HP HR)	5.46 (4.07)
BSCO2 G/KW HR (G/HP HR)	814. (607.)
BSNOX G/KW HR (G/HP HR)	7.41 (5.53)
BSFC KG/KW HR (LB/HP HR)	.259 (.426)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	6.95
	G/KWHR(G/HPHR)	.37 (.28)
	G/KG FUEL (G/LB FUEL)	1.45 (.66)
	FILTER EFF.	95.8

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA 460/3-84-008	2.
3. RECIPIENT'S ACCESSION NO.	
4. TITLE AND SUBTITLE Heavy-Duty Engine Exhaust Particulate Trap Evaluation	5. REPORT DATE September 1984
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Charles M. Urban	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Southwest Research Institute 6220 Culebra Road San Antonio, Texas 78284	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO. 68-03-3162 Work Assign, No. 3
12. SPONSORING AGENCY NAME AND ADDRESS Environmental Protection Agency 2565 Plymouth Raod Ann Arbor, Michigan 48105	13. TYPE OF REPORT AND PERIOD COVERED Final (7/25/83 - 7/25/84)
	14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES	

16. ABSTRACT

This report describes a laboratory effort to evaluate several aspects of the use of exhaust particulate traps with heavy-duty diesel engines. The effort involved: monitoring exhaust temperatures in heavy-duty vehicles operating on a chassis dynamometer; design and evaluation of a particualte trap bypass system; regeneration of particulate traps; and exhaust emissions evaluations of a heavy-duty diesel engine, with and without exhaust particulate traps.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Exhaust Emissions Diesel Engines	Heavy-Duty Engines Particulate Emissions Control	

18. DISTRIBUTION STATEMENT Release Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 66
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

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PUBLICATION NO. EPA 460/3-84-008